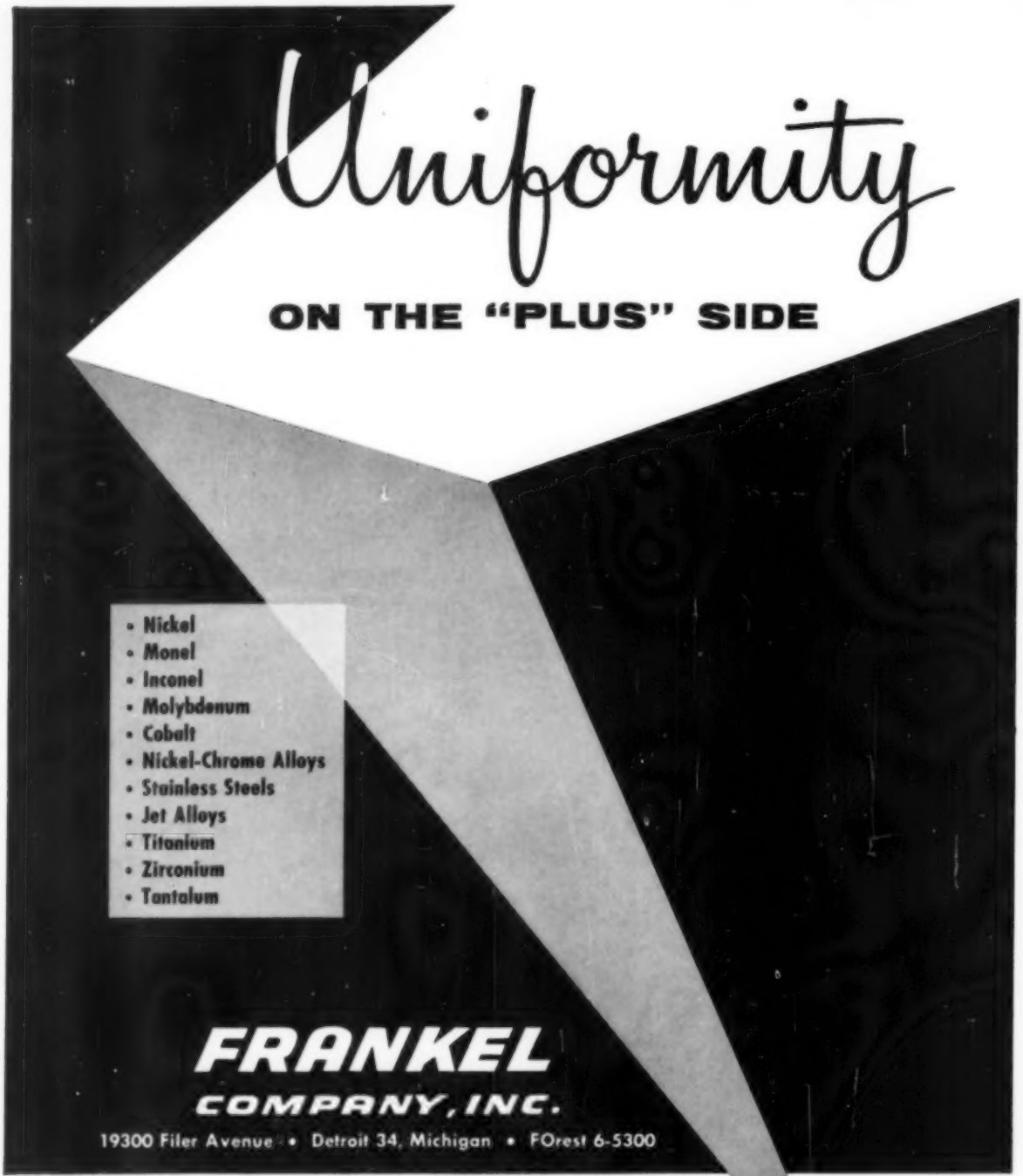
JOURNAL OF

METALS

FEBRUARY 1961



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JOURNAL OF

METALS

Vol. 13, No. 2
February, 1961

COVER: Highlighting "Metallurgy in the Army"—based on a symposium by the same name held at the 1960 Fall Meeting—our cover artist, David Cain, produced this soldier with tanks.

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personnel

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If you are interested in any of these listings, and are not registered, you may apply by letter or resume and mail to the office nearest your place of residence, with the understanding that should you secure a position as a result of these listings you will pay the regular placement fee. Upon receipt of your application a copy of our placement fee agreement, which you agree to sign and return immediately, will be mailed to you by our office. In sending applications be sure to list the key and job number.

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Research and Development Staff Metallurgist. B.S. Ch.E. 1951, M.S. Ch.E. 1959, M.B.A. candidate 1962. Nine years metallurgist, MS degree plus graduate business management study; 9 years applied research experience as project leader in physical metallurgy and fabrication of ferrous, non-ferrous and refractory materials. Desire supervisory position with growth potential. Prefer East coast. M-248.

Metallurgical Engineer, B.S. Met. Eng., age 36. Three years cast shop metallurgical brass rolling mill, plus 5 years metallurgical and plant manager aluminum green sand foundry; 1½ years sales engineering ferrous castings. Very adaptable to specific needs. M-2056-Chicago.

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Recent Graduate Engineers, B.S. or M.S. in engineering, physics or science, in particular B.S. or M.S. in nuclear, mechanical, chemical, electrical, metallurgy or physics, for nuclear engineering program, to fill internship program. Will be assigned to various laboratories throughout the US. Salary to start, $6345, with promotion to $6875 after eleven months; $7260 upon completion of training. Headquarters, Washington, D.C. W9890.

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La Revue de Metallurgie was created in 1904 by Henry Le Chatelier. In June 1959 it changed format, now appearing in two separate monthly parts.

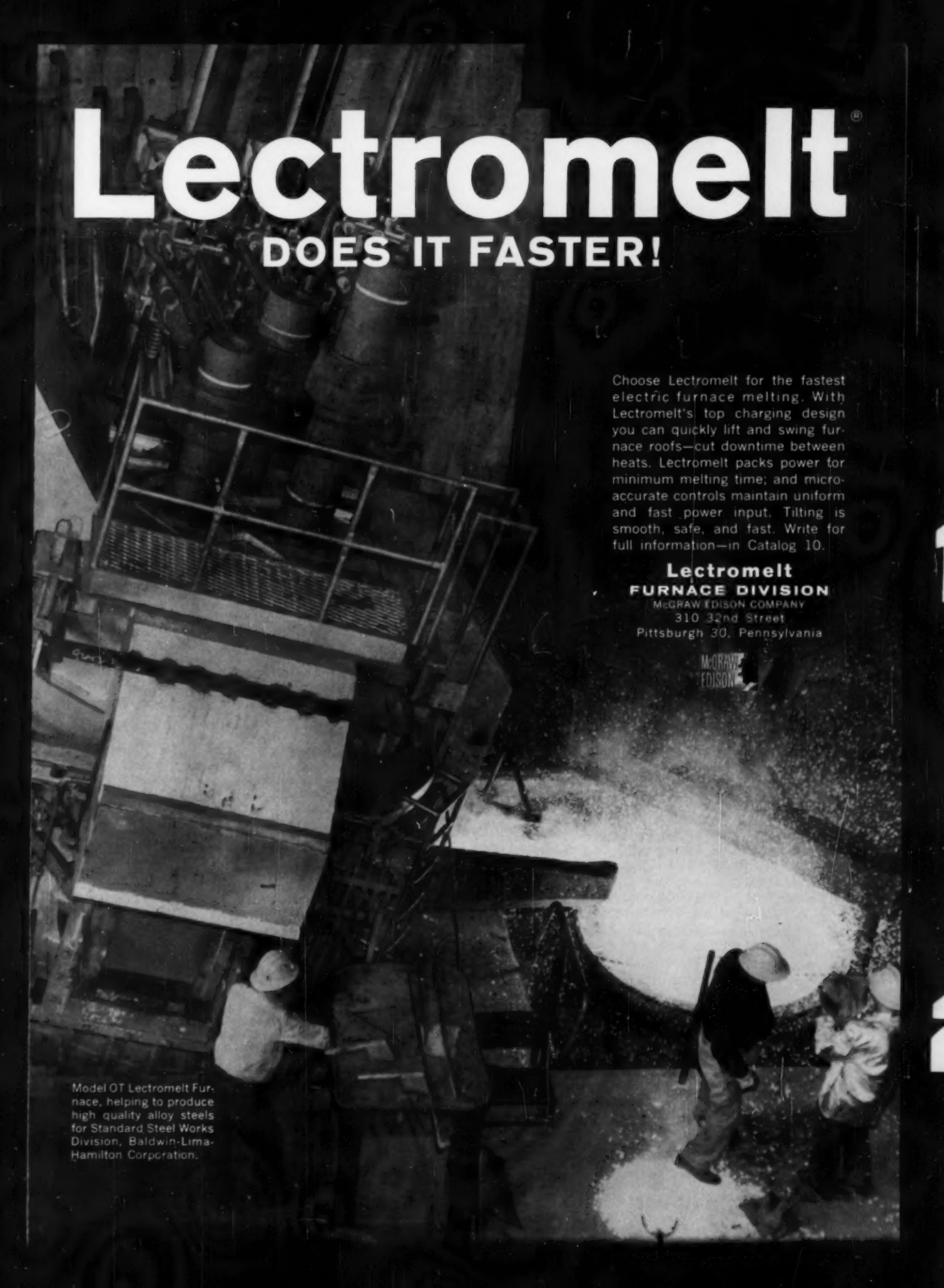
One part, which preserves the title **Revue de Metallurgie,** is devoted particularly to applied metallurgy, especially the manufacture and working of ferrous and nonferrous metals.

It also includes economic and statistical reports, as well as news of activities of the Societe Francaise de Metallurgie and related institutions.

The second part of the magazine maintains the scientific character of the former publication and, as in the past, includes separate sections devoted to original papers and to abstracts. The title of this part is **Memoires Scientifiques de La Revue de Metallurgie.**

Subscription rates for 1960

Revue de Metallurgie	**$16.50**
Memoires Scientifiques de la Revue de Metallurgie	**$35**
Both publications jointly	**$47**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new books

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Book Reviews

In order to give more complete coverage to books dealing with metallurgy, the JOURNAL OF METALS will publish a short review of each important addition to metallurgical literature. These reviews will be written by well-known authorities in the particular field of metallurgy under consideration.

Cermets edited by J. R. Tinklepaugh and W. B. Crandall, Reinhold Publishing Corp., 245 pp., $9.50, 1960. *Reviewed by Earl R. Parker, University of California.*

This 239-page book is a compilation of 24 separate contributions, ranging in length from one half a page to 44 pages. The author of each article is a recognized expert in the subject about which he has written. This book should be considered indispensable reading material for metallurgists and engineers who need to become acquainted with cermet materials. Independent view points and specialized information are presented about theory, experimental methods, production methods, properties, and uses of cermets.

The contributions of the 23 authors provides a perspective of the subject that would be very difficult to acquire without reference to this monograph. An excellent presentation of theoretical considerations is given in the longest article in the text. Nearly a hundred special references are appended to this article; almost all of the other contributions are supplemented with similar lists of special references. In addition, a comprehensive bibliography of 545 general references is provided at the end of the book.

Eight articles, comprising 46 pages, describe methods of preparation and fabrication of cermets. The subject matter covered in this section of the book is broad, including slip casting, infiltration processes, resistance sintering, and explosive isostatic forming. The properties and uses of metal-oxide cermets are discussed in several articles, as are properties of metal-carbide materials. Further breadth of coverage is provided by discussions of special cermets, such as refractory materials, electronic materials, and those used where friction is a controlling consideration. Special contributions are also included on the application of cermets to nuclear devices, and the use of cermets in aircraft power plants.

This book provides a good introduction to the subject of cermets, but the depth to which each subject is developed is limited because of space restrictions.

• • •

Crystal-Structure Analysis by Martin J. Burger, John Wiley and Sons, Inc., 668 pp., $18.50, 1960. *Reviewed by Paul A. Beck, University of Illinois.*

Since discovery of the diffraction of X-rays by crystals 48 years ago, X-ray diffraction has become an increasingly-useful tool for the metallurgist. Its use in this area is now so widespread that no self-respecting Metallurgy Department at any institute of higher learning would consider its undergraduate curriculum complete without at least an introductory course on the subject.

During the last 25 years, the X-ray diffraction apparatus has taken its place alongside the metallographic microscope as standard equipment in industrial metallurgical laboratories as well. Among the many metallurgical uses of X-ray diffraction, crystal-structure analysis is one not yet normally entrusted to metallurgists. Rather it is apparently considered as the domain of a species of superior intellectual powers, the crystallographers. Nevertheless, knowledge of the techniques is rapidly spreading, and it is becoming increasingly important also to many metallurgists engaged in research.

The first eight chapters of the present book provide a framework of the fundamental concepts which constitute the prerequisites for structure analysis. The subsequent 15 chapters give a thorough and detailed treatment of such subjects as the number of atoms in the unit cell, the structure factor, plane projections, structure factor calculations, examples of the determination of some simple crystal structures, Fourier synthesis, reciprocal space, symmetry in recriprocal space, applications of symmetry to Fourier summations, practical methods of summing Fourier series, phase determination for structures having a set of heavy and replaceable atoms, phase determination for some special cases, direct determinations and refinement. The treatment is extremely lucid and readable throughout, as one has come to expect on the basis of the series of excellent textbooks written previously by the very well-known author, who is professor of mineralogy and crystallography at M.I.T. Each chapter is followed by

(Continued on page 106)

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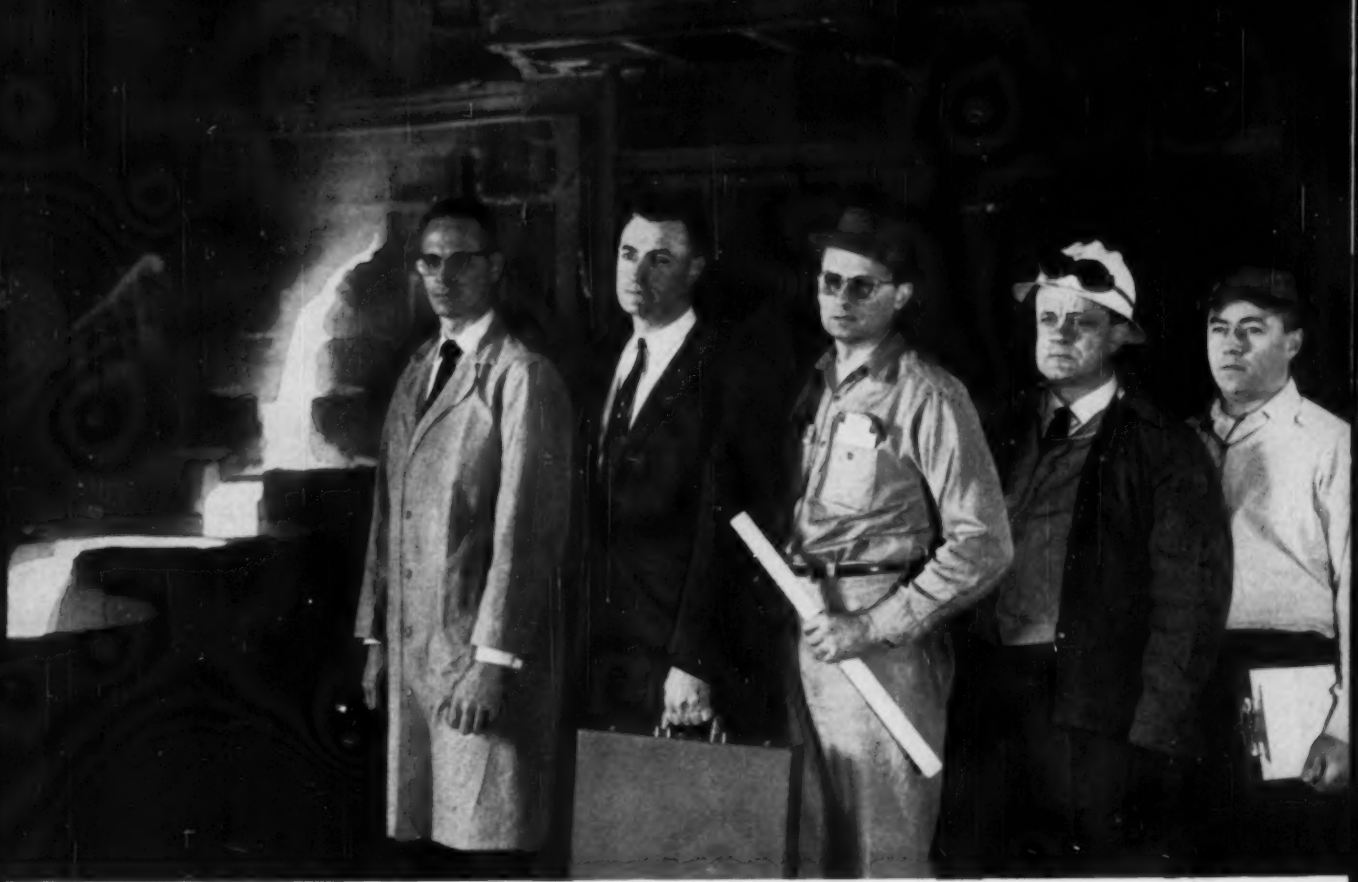

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New Books

(Continued from page 104)

a list of well-chosen references, that should help the advanced reader in finding access to additional details.

This book represents probably one of the most advanced textbooks on the techniques of crystal-structure analysis. For the average metallurgy undergraduate or beginning graduate student, the author's *X-ray Crystallography*, or the Elements of *X-ray Diffraction* by B. D. Cullity would presumably be used to start acquiring a basic understanding of X-ray diffraction methods. The latter books, and the well-known *Structure of Metals* by C. S. Barrett, may serve to acquaint the student with other applications of X-ray diffraction to metallurgical problems, outside of crystal-structure analysis proper. For the student or research metallurgist who has already gone through such basic training and wishes to learn the particular techniques involved in crystal-structure analysis by means of diffraction, Professor Burger's book can be very highly recommended.

• • •

Transformers and Generators for Power Systems, by R. Langlois-Berthelot, published by Philosophical Library, Inc., New York. This book is for the engineering student who has a knowledge of physics, for the engineer concerned with design and manufacture, and for the operating engineer. $12.00. •

Proceedings of the Fifth Conference on Magnetism and Magnetic Materials, edited by J. A. Osborn, published by McGraw-Hill Book Co., New York. This volume contains papers presented at the Conference on Magnetism and Magnetic Materials, held in Detroit, November 16-19, 1959. $10.00. •

The Dynamic Behavior of Thermoelectric Devices, by Paul E. Gray, published jointly by Technology Press of Massachusetts Institute of Technology and John Wiley & Sons, Inc., New York. This book investigates the small-signal dynamic behavior of thermoelectric devices. •

Oxide Ceramics, by Eugene Ryshkewitch, Academic Press, New York, 472 pp., $16.00, 1960—This book deals principally with ceramics of single phase oxide systems from the standpoint of physical chemistry and of technology in both its aspects; production and application. It is based on, but not a translation of, the author's **Oxydkeramik der Einstoff-Systeme (1948).** Part one describes the general fundamentals of oxide ceramics. Part two deals with specific sintered oxide ceramics—alumina, spinel, magnesia, beryllia, zirconia, zircon, thoria, and ceria—and gives, in the final chapter, a brief description of substantially two-phase systems, composed of oxides with metals or with carbides. •

Tinplate Testing-Chemical & Physical Methods, by W. E. Hoare and S. C. Britton, Tin Research Institute, 55 pp., 1960—This handbook will be useful to those who are responsible for the quality appraisal of tinplate and the determination of the suitability of particular grades for specific uses. It is limited to the superficial layers of the tinplate. It does *not* describe mechanical testing procedures. Quality test methods for thickness and continuity of the tin coating, and the determination of the oxide and oil films are discussed and compared; also considered are performance tests for rust resistance, staining, lacquerability, solderability, and corrosion. The book contains 24 illustrations and diagrams. It is obtainable *free* of charge from the Tin Research Institute, Fraser Road, Perivale, Greenford, Middlesex, England; or from Tin Research Institute, Inc., 492 West Sixth Ave., Columbus, Ohio. •

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Sponsored by the Blast Furnace, Coke Oven, and Raw Materials Committee and the National Open Hearth Steel Committee of the Iron and Steel Division of The Metallurgical Society of AIME

Sheraton Hotel, Philadelphia — April 10-12, 1961

CONDENSED OPEN HEARTH PROGRAM

Monday, April 10

General Session

9:30 am

Welcoming Remarks: *L. W. Moore*, Assistant General Manager, Wheeling Steel Corp., Steubenville, Ohio.

Announcements and Reports

McKune Award Paper

Basic Operations

10:15 am

Potential of the Open Hearth: *George Ferris*, Operations Manager, Ingot Production and Primary Mills, Ford Motor Co., Dearborn, Mich.

Some Aspects of High-Oxygen Practice at Great Lakes: *Ralph Duffett*, Superintendent of Open Hearths and Bessemers, Great Lakes Steel Corp., Ecorse, Detroit, Mich.

Comparison of Practices With Oxygen-Fuel Burners and Oxygen Lances: *T. B. Winkler*, Division Head, Process Metallurgy Section, Research Department, Bethlehem Steel Corp., Bethlehem, Pa.

Acid Operations

10:15 am

Some Problems Encountered in the Use of Deuterium as a Tracer Element for Hydrogen In Steel: *J. H. Dudas*, Research Engineer, University of Pittsburgh, Pittsburgh, Pa., and *R. C. McCoy*, Research Engineer, Acid Open Hearth Research Association, Inc., Pittsburgh, Pa.

Preparation of Steel With Low-Gas Content in the Acid Open Hearth Process: *G. R. Fitterer*, Director of Research, and *R. C. McCoy*, Research Engineer, Acid Open Hearth Research Association, Inc., Pittsburgh, Pa.

Deoxidation by Vacuum: *E. Pyble*, Metallurgical Engineers, and *G. A. Taylor*, Melting Department, Erie Forge Co., Erie, Pa.

Acid Bessemer Process

10:15 am

Formation and Suppression of Smoke in Pneumatic Steelmaking Processes: *G. W. P. Rengstorff*, Assistant Chief, Metals Science Group, Battelle Memorial Institute, Columbus, Ohio.

Recent Developments in the Basic Bessemer (Thomas) Process in Europe: *G. M. Yocom*, Assistant to General Manager, Wheeling Steel Corp., Steubenville, Ohio.

Round Table Discussion:

Moderator: *A. B. Wilder*, Chief Metallurgist, National Tube Division, U. S. Steel Corp., Pittsburgh, Pa.

Tentative Agenda—

- Safety in Bessemer Shop
- Hot Metal—Quality of Iron
- Refractories for the Converter—Mixers and Ladles
- Vessel Operation—Blowing and Pouring Practices
- New Developments

Operating Metallurgy I—Manufacture of Large Rimming and Bottle Top Steel Ingots for Sheet Applications

2:00 pm

Solidification of Open Hearth Steels:

a. Some Origins of Structures in Rimmed and Partially Killed Ingots: *B. M. Larsen*, Assistant Director, Fundamental Research Laboratory, U. S. Steel Corp., Monroeville, Pa.

Manufacture of Large Rimming Steel Ingots:

a. Metallurgical Problems Encountered in the Manufacture of Large Rimming Steel Ingots: *H. F. Lesso*, Senior Steel Plant Metallurgist, Great Lakes Steel Corp., Ecorse, Detroit, Mich.

b. Metallurgical Aspects in the Manufacture of Large Rimming Steel Ingots: *B. W. Bowen*, Republic Steel Corp., Cleveland, Ohio.

Manufacture of Large Mechanically Capped Ingots:

a. Use of Large Bottle Top Ingots for the Manufacture of Flat Rolled Products: *M. Tarris* and *Leonard Pucker*, Granite City Steel Co., Granite City, Ill.

b. Adoption of Large Mechanically Capped Ingots to Sheet Applications: *L. R. Walker, J. O. Mack,* and *J. F. Georgiadis,* Fairless Works, U. S. Steel Corp., Fairless Hills, Pa.

Refractories I

2:00 pm

Prefabrication of Open Hearth Furnace Sections:

a. Prefabrication of Open Hearth Basic Ends and Port Roofs: *L. R. Lattimore,* Superintendent, Masonry Department, Lone Star Steel Co., Lone Star, Texas.

b. Prefabrication Sections in a Maerz-Boelens Type Open Hearth Furnace: *L. B. Lindemuth,* Open Hearth Superintendent, Keystone Steel and Wire Co., Peoria, Ill.

Ladle Gunning: *D. Saylor,* General Foreman, Masonry Department, Ford Motor Co., Dearborn, Mich.

A Refractories Quality Control Program for Steel Plants: *A. Sontz,* General Supervisor, Ceramics Department, and *E. C. Rudolphy,* Assistant Chief Metallurgist, South Works, U. S. Steel Corp., Chicago, Ill.

Basic Oxygen Steelmaking Refractories:

a. Wear Patterns of L-D Vessel Linings: *J. R. Atkinson,* Superintendent Steelmaking, Dominion Foundries and Steel, Ltd., Hamilton, Ontario, Canada

b. Developments in Lining Refractories for the Basic Oxygen Process: *J. N. Albaugh,* Superintendent Steel Production, Aliquippa Plant, Jones & Laughlin Steel Corp., Aliquippa, Pa.

c. Techniques of Lining L-D Vessels: *F. C. Muttitt,* Assistant Superintendent, Masonry, Algoma Steel Corp., Sault Ste. Marie, Ontario, Canada.

Tuesday, April 11

Refractories (II)

9:30 am

A. Basic Brick Today and Tomorrow.

Current Status of Basic Brick Technology: *George Eusner,* Chief Refractory and Mineral Technology Division, Applied Research Laboratory, U. S. Steel Corp., Monroeville, Pa.

Basic Brick for the Future: *H. M. Kraner,* Division Head, Ceramics, Development and Research Department, Bethlehem Steel Corp., Bethlehem, Pa.

B. Basic Roof Life as Affected by Combustion Practices.

Productivity and Refractory Consumption for Various Combinations of Fuel and Oxygen Rates: *T. W. Trumper,* Practice Engineer, Open Hearth, Steel Co. of Canada, Ltd., Hamilton, Ontario, Canada.

Automatic Control for Maximum Heat Input for Basic Roof Open Hearth Furnace With Oxygen Roof Lances: *Jacob Belkin,* Research Technologist, U. S. Steel Corp., Monroeville, Pa.

C. Basic Roof Maintenance.

Patching and Maintaining Basic Roofs: *Keith Bartels,* Superintendent, Masonry Department, Fairless Works, U. S. Steel Corp., Fairless Hills, Pa.

Construction, Maintenance, and Patching of Basic Roofs: *Frank Pikus,* Superintendent, Masonry Department, Columbia-Geneva Steel Division, U. S. Steel Corp., Provo, Utah.

Patching Techniques for Basic Roofs: *F. J. La Rocca,* Ceramic Engineer, Colorado Fuel and Iron Corp., Pueblo, Colo.

Basic Oxygen Process

9:30 am

Introductory Remarks:
A. B. Wilder, Chief Metallurgist, National Tube Division, U. S. Steel Corp., Pittsburgh, Pa.

New Facilities: *George Grosvenor,* Superintendent Open Hearth, Colorado Fuel and Iron Corp., Pueblo, Colo.

New Facilities: *John Glasgow,* Open Hearth Superintendent, Jones & Laughlin Steel Corp., Cleveland, Ohio.

Air Pollution Control in Oxygen Steelmaking: *J. H. Smith,* Director, Air Control and Research, Kaiser Steel Corp., Fontana, Calif.

Design and Construction of Great Lakes Basic Oxygen Plant: *Richard Morgan,* Assistant Superintendent, No. 2 Open Hearth, Great Lakes Steel Corp., Ecorse, Detroit, Mich.

Panel Discussion on Automation:
C. C. Benton, Division Superintendent, Algoma Steel Corp., Sault Ste. Marie, Ontario, Canada.
J. R. Atkinson, Superintendent Steelmaking, Dominion Foundries and Steel Co., Ltd., Hamilton, Ontario, Canada.
Representative of Acme Steel Co.
Representative of Jones & Laughlin Steel Corp.

Operating Metallurgy (II)

2:00 pm

Process Kinetics of Basic Oxygen Steelmaking: *W. O. Philbrook,* Professor of Metallurgical Engineering, Carnegie Institute of Technology, Pittsburgh, Pa.

Relation Between Inclusions, Oxygen Contents, and Defects in Seamless Tube Steels: *N. L. Samways,* Research Supervisor, and *E. J. Paliwoda,* Senior Research Engineer, Jones & Laughlin Steel Corp., Pittsburgh, Pa.

Behavior of Columbium in Liquid Steel: *R. W. Joseph,* Supervising Metallurgist and *J. T. Mareta,* Metallurgist, Metallurgical Department, Inland Steel Co., East Chicago, Ind.

Exothermic Sideboard Hot Tops: *W. E. Bayers, Jr.,* Chief Metallurgist, and *C. D. Boyle,* Chief Process Metallurgist, Edgar Thomson Works, U. S. Steel Corp., Braddock, Pa.

Combustion and Operations

2:00 pm

Rates of Oxidation and Heating of Scrap in Open Hearth Furnaces: *P. J. Koros,* Senior Research Engineer, *B. G. Nordstrom,* Research Engineer, and *J. A. Smik,* Research Engineer, Jones & Laughlin Steel Corp., Pittsburgh, Pa.

High Usage of Natural Gas: *W. H. Kahl,* Assistant Superintendent No. 2 Open Hearth, Inland Steel Co., East Chicago, Ind.

Combustion Control in Open Hearth Furnaces: *R. E. Stoll,* Chief Process Metallurgist, *G. C. Primm,* Superintendent, Fuel Utilization, and *E. C. Rudolphy,* Assistant Chief Metallurgist, South Works, U. S. Steel Corp., Chicago, Ill.

Pouring Pit Maintenance: *W. Redmond,* General Foreman, Casting Department, Republic Steel Corp., Buffalo, N. Y.

Ingot Molds and Stools Made at Lone Star Steel Company: *R. C. Harrell,* Superintendent of Foundries, Lone Star Steel Co., Lone Star, Texas.

Prefabricated Furnace Installation: *A. Tunia,* Superintendent of Construction, Great Lakes Steel Corp., Ecorse, Detroit, Mich.

Tuesday, April 11

Cold Metal and Basic Foundry

2:00 pm

Methods for Evaluating Refractories: *F. H. Hohn*, Assistant to the Works Manager and Chief Metallurgist, Scullin Steel Co., St. Louis, Mo.

Use of the Natural Gas-Oxygen Burner in All-Cold Metal Open Hearth Furnaces: *E. W. Ganslein*, The Buckeye Steel Casting Co., Columbus, Ohio.

Improved Chromium Recovery Control in the Open Hearth: *D. R. Haines*, Assistant Plant Metallurgist, and *A. K. Wilson*, General Steel Castings Corp., Eddystone, Pa.

Round Table Discussion: Intermittent Operations and Week-End Shutdowns
G. W. Teskey, Superintendent, Open Hearth, Bethlehem Pacific Coast Corp., South San Francisco, Calif.

C. J. McElhaney, Superintendent Open Hearth, Pittsburg Works, Columbia-Geneva Steel Division, U. S. Steel Corp., Pittsburg, Calif.

W. H. Steinheider, General Foreman, Open Hearth, Sheffield Division, Armco Steel Corp., Kansas City, Mo.

W. F. Low, Project Engineer, John A. Roebling's Sons Division, Colorado Fuel and Iron Corp., Trenton, N. J.

CONDENSED BLAST FURNACE PROGRAM

Monday, April 10

Blast Furnace Practice Session

9:00 am

Effect of Sinter Size on Blast Furnace Productivity: *N. D. Macdonald*, General Works Manager, Workington Iron and Steel Co., Ltd., Workington, Cumberland, England.

Operating Results Using Taconite Pellets in Armco's Middletown No. 3 Blast Furnace: *K. R. Haley*, Superintendent, Blast Furnaces, Armco Steel Corp., Middletown, Ohio.

Experimental and Commercial Blast Furnace Probe Experience: *J. C. Agarwal*, Research Associate, *H. R. Pratt*, Assistant Technologist, Applied Research Laboratory, U. S. Steel Corp., Monroeville, Pa., and *R. H. White*, Division Superintendent, Fairless Works, U. S. Steel Corp., Fairless Hills, Pa.

Coal Session

9:00 am

Bench-Scale Experiments in Developing Anthracite Metallurgical Briquets: *W. S. Sanner*, Supervising Chemical Engineer, *R. E. McKeever*, Chemical Engineer, and *J. W. Eckerd*, Chief, Branch of Utilization and Preparation, Anthracite Research Center, U. S. Bureau of Mines, Schuylkill Haven, Pa.

Recent Developments in Coal Petrography: *N. Schapiro*, Supervising Technologist, Anthracology Section, *R. J. Gray*, Senior Technologist, Anthracology Section, and *G. R. Eusner*, Division Chief, Refractory and Mineral Technology Division, Applied Research Laboratory, U. S. Steel Corp., Monroeville, Pa.

The Maple Creek Preparation Plant: *L. U. Anderson*, General Plant Foreman, Maple Creek Preparation Plant, U. S. Steel Corp., Uniontown, Pa.

Storage of High-Volatile Coal at Pueblo Plant of Colorado Fuel and Iron Corporation: *J. R. Purdy*, Assistant Superintendent, By-Product Coke Plant, The Colorado Fuel and Iron Corp., Pueblo, Colo.

Blast Furnace Theory Session

2:00 pm

Idealized Heat Transfer From a Gas Stream to Granular Solids: *J. F. Elliott*, Professor of Metallurgy, and *J. C. Humbert*, Massachusetts Institute of Technology, Cambridge, Mass.

Significance of Size Distribution, High-Temperature Strength, and Reactivity of Coke in the Blast Furnace and Cupola: *H. Echterhoff*, Chief Engineer, Carbonization Research, *W. Peters*, Section Manager, Processing and Technology Dept., Bergbau-Forschung, G.m.b.H., Essen-Kray, Germany, and *K. G. Beck*, Chief, Coke Department, Steinkohlenbergbauvereins, Essen, Germany.

Theoretical Considerations on the Injection of Auxiliary Fuels into the Blast Furnace: *A. M. Decker*, Chief Research Engineer, Centre National de Recherches Metallurgiques, Abbaye Du Val-Benoit, Liege, Belgium.

Coal Chemicals Session

2:00 pm

Diammonium Phosphate—From Phosphate Rock and Coal to Fertilizer and Fire-Retardant: *W. G. Schulze*, Superintendent, Coke and Coal Chemicals Plant, Kaiser Steel Corp., Fontana, Calif.

Removal of Thiophene Sulfur From Benzene and Toluene by Means of Sulfuric Acid Washing: *Richard Muder*, Senior Scientist, *Joseph Kovacic*, Scientist, and *George Bretz*, Scientist, Research Department, Koppers Co., Inc., Verona, Pa.

Ammonia and Urea From Steelmaking By-Products: *S. J. Viron*, Assistant Technical Director, Cyanamid of Canada, Hamilton, Ontario, Canada.

Steam Economy for Wash Oil Stripping Systems: *Y. C. Chang*, Technologist, Applied Research Laboratory, U. S. Steel Corp., Monroeville, Pa.

Iron Ore Reduction Session

2:00 pm

Allis-Chalmers Agglomeration—Reduction Process: *T. G. Kirkland*, Supervisor, Applied Research, *C. L. Sollenberger*, Supervisor, Process and Mechanical Research, *J. L. Platner*, Engineering Scientist in Charge, Applied Research, and *W. W. Edens*, Assistant Director, Research Division, Allis-Chalmers Manufacturing Co., Milwaukee, Wisc.

Kinetics of Reduction of Sintered Iron Ore With Minor Compound Additions: *J. H. Cox*, Research Associate, and *H. U. Ross*, Associate Professor of Metallurgical Engineering, University of Toronto, Toronto, Ontario, Canada.

Reduction of Iron Ore Particles in Beds: *A. E. El-Mehairy*, Research Metallurgical Engineer, and *W. O. Philbrook*, Professor of Metallurgical Engineering, Carnegie Institute of Technology, Pittsburgh, Pa.

Steelmaking by the HyL Direct Reduction Process: *R. Lawrence, Jr.*, Sales Manager, Iron and Steel Division, The M. W. Kellogg Co., New York, N. Y.

Tuesday, April 11

Sintering Session

9:00 am

Generation and Treatment of Sinter Plant Dusts: *P. A. Young*, General Manager, Research and Development Division, Head Wrightson and Co., Ltd., Thornaby-On-Ties, England.

United States Steel Hot Ore Briquetting Process: *R. G. Thompson*, Chief, Raw Materials Engineering Division, *D. E. Rohaus*, Associate Technologist, and *J. R. Guseman*, Associate Technologist, Applied Research Laboratory, U. S. Steel Corp., Monroeville, Pa.

Blast Furnace Practice With 100 Per Cent Low-Grade Self-Fluxing Sinter: *J. Michard*, Institut de Recherches de la Sidérurgie, Maizières-les-Metz, Moselle, France, and *G. Chanty*, Head, Metallurgical Department, De Wendel Co., France.

Sinter Bed Ignition:
J. M. Ridgion, British Iron and Steel Research Association, Normanby, Middlesbrough, England.

Coke Session

9:00 am

Coke Oven Battery Innovations and Coal and Coke Preparation Facilities of the Coking Plant Kattwyk of the Hamburger Gaswerke, G.m.b.H.: *George Düwel*, Director, Hamburger Gaswerke, G.m.b.H., Hamburg, Germany

Relation of Properties of Coke Produced by the BM-AGA and Industrial Methods: *D. E. Wolfson*, Chief, Coal Carbonization Section, *G. W. Birge*, Chemical Engineer, and *J. G. Walters*, Chemist, U. S. Bureau of Mines, Pittsburgh, Pa.

Reactivity, Size Distribution, and High Temperature Strength of Coke and How They are Affected by the Coking Process: *H. Echterhoff*, Chief Engineer, Carbonization Research, and *W. Peters*, Section Manager, Processing and Technology Department, Bergbau-Forschung G.m.b.H., Essen-Kray, Germany, and *K. G. Beck*, Chief, Coke Department, Steinkohlenbergbauvereins, Essen, Germany.

A Study of Combustion Conditions During Reversal with Blast Furnace Gas Underfiring: *A. M. Cameron*, Technical Assistant, Coke Plant, and *G. W. Sagle*, Coke Plant Engineer, The Algoma Steel Corp., Ltd., Sault Ste. Marie, Ontario, Canada.

Computer Application Session

9:00 am

What Are Computers?: *D. C. McCune*, Senior Statistician, and *J. C. Buker*, Research Engineer, Johns & Laughlin Steel Corp., Pittsburgh, Pa.

Mathematical Method for Analyzing and Predicting Changes in Blast Furnace Operations: *A. L. Hodge*, Associate Manager, Gas Processes Development, and *E. R. Wyczalek*, Development Engineer, Linde Company, Division of Union Carbide Corp., Newark, N. J.

Computer Applications in the Blast Furnace Area: *D. S. Macoy*, Staff Supervisor, Computer Programming, Gary Steel Works, U. S. Steel Corp., Gary, Ind.

Joint Session

2:00 pm

Iron Ore—The Big Picture: *E. H. Rose*, Chief Beneficiation Engineer, Koppers Co., Inc., Pittsburgh, Pa.

Application of Centralized Control to a Combined Mine and Coking Plant (Includes Motion Picture, "The Murton Coking Plant"): *M. D. Edington*, Carbonization Director, National Coal Board, Gateshead, County Durham, England

Panel Discussion: Carbonaceous Fuel Additives to the Blast Furnace Hot Blast:
Moderator: *D. H. Regelin*, Assistant Chairman, Operating Committee, Iron Production, U. S. Steel Corp., Pittsburgh, Pa.

Panel:

Joel Rameriz, Blast Furnace Superintendent, Altos Hornos de Mexico, S. A., Monclava, Coah., Mexico.

J. W. Carlson, Superintendent, Blast Furnace Department, Colorado Fuel and Iron Corp., Pueblo, Colo.

S. G. Anderson, Division Superintendent, Iron Production, Lone Star Steel Co., Lone Star, Texas.

E. R. Dean, Assistant General Superintendent, Coal and Iron Division, Pittsburgh Coke and Chemical Co., Pittsburgh, Pa.

H. C. Taylor, Superintendent, Blast Furnaces and Coke Plant, Dominion Foundries and Steel, Ltd., Hamilton, Ontario, Canada.

R. H. White, Division Superintendent, Blast Furnaces, Coke and Chemical Works, Fairless Works, U. S. Steel Corp., Fairless Hills, Pa.

W. M. Kreglow, Jr., Technical Assistant to Vice President, Bethlehem Steel Co., Bethlehem, Pa.

General Information

Plant Trip: Through the courtesy of Bethlehem Steel Company, an inspection trip has been arranged to their Sparrows Point plant on Wednesday, April 12. Registrants will have the opportunity of visiting either No. 4 Open Hearth Department, new soaking pits, and blooming mill, or the sintering plant, coke ovens, and blast furnaces. Lunch will be served, courtesy of Bethlehem Steel Company.
A special train will be operated by the Pennsylvania Railroad directly to the plant. The train will depart from the Philadelphia Suburban Station (adjacent to the Sheraton Hotel and connected by underground passageway) at 7:35 am. Returning, the train will leave Sparrows Point at 2:30 pm, and is scheduled to arrive in Philadelphia at 5:00 pm. For those who do not wish to return to Philadelphia, bus transportation will be provided from Sparrows Point to the airport and railroad stations in Baltimore.
A charge of $5.50 will be made to defray the expense of the plant trip, railroad costs, and federal transportation tax. (Use of private cars will not be permitted. Please cooperate by using the special train.)

Fellowship Dinner Reservations: The Fellowship Dinner will be held in the Ballroom of the Sheraton Hotel on Tuesday evening, April 11. All tickets will be assigned to tables as orders are received. To avoid confusion, you are urged to reserve complete tables of ten in advance, by sending a check for $120.00 for each table desired to A. E. Bickell, General Refractories Company, 1520 Locust Street, Philadelphia 2, Pa. Please make all checks payable to AIME. Tickets will be mailed to you in March.
Single tickets at $12.00 each should be ordered from AIME headquarters, 29 West 39th Street, New York 18, New York. Reservation forms for single tickets will be sent to past-registrants early in March.

General Information

Hotel Reservations: Adequate hotel facilities will be provided at the Sheraton Hotel and other Philadelphia hotels. Hotels, however, will not hold blocks of rooms assigned to this meeting after March 31. Single rooms are limited. Hotel reservation requests should, therefore, be sent to the hotel of your choice as soon as possible. Be sure to mention the Blast Furnace Conference or the Open Hearth Conference of AIME as well as the time of arrival in making your request.

General Invitation: All operating men, repair and maintenance men, metallurgists, ceramic and refractory engineers, observers, and any others interested in the production of more steel, better steel, and cheaper steel, and in any of the problems connected with the reduction of iron ore in the blast furnace, are invited to attend. The complete program will be mailed in March, but make plans now to attend this important Conference.

The registration fee for either Conference is ten dollars ($10.00), which includes a copy of the respective Proceedings when printed. There is no registration fee for students at any of the sessions, unless they desire a copy of the Proceedings. AIME members are entitled to a three dollar ($3.00) reduction in the registration fee upon presentation of their membership card.

Both meetings promise to be extremely interesting and it is worthwhile to register for both in order to receive both volumes of Proceedings.

Special Notice—First International Symposium on Agglomeration

The First International Symposium on Agglomeration, under the auspices of AIME, will be held at the Sheraton Hotel, Philadelphia, April 12-14, directly following the technical sessions of the National Open Hearth Steel Conference and the Blast Furnace Conference. All are invited to remain at the Sheraton Hotel and to attend this important conference.

The theme is Agglomeration—all phases of sintering, pelletizing, nodulizing, briquetting, and powder metallurgy as related to ferrous, nonferrous metallic and non-metallic materials.

Registration fees, which include a copy of the Symposium Proceedings, follow:

Members—AIME	$25.00
Non-Members	27.50

Preprints will be sent to all who register in advance before April 1.

For further information, or to register, please address:

Mr. William S. Cumings, Finance Chairman
International Symposium on Agglomeration,
AIME
29 West 39th Street
New York 18, New York

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WE'RE REACHING INTO SPACE

Bell Laboratories research with chilled ruby amplifiers speeds the day we may telephone via satellites

A strange combination of Nature's forces at Bell Laboratories foreshadows the day when world-wide phone calls may be relayed via man-made satellites orbiting the earth. It is a union of synthetic rubies and extreme cold, making it possible to amplify microwave signals from these satellites clearly.

Synthetic rubies possess an extraordinary property when deeply chilled and subjected to a magnetic field. They can be excited to store energy at the frequencies of microwave signals. As a signal passes through an excited ruby, it releases this energy and is thus amplified a thousandfold.

Bell Laboratories scientists chose a ruby amplifier because it's uniquely free of "noises" that interfere with radio signals. For example, it doesn't have the hot cathodes or hurtling electrons that generate noise in conventional amplifiers. It is so quiet that only the noise made by matter itself in heat vibrations remains. But at a temperature close to absolute zero, this also is silenced. Even very faint signals from satellites can be clearly amplified and studied for their possibilities.

Bell Laboratories scientists were first to discover that matter itself generates electrical noise. They also discovered that stars send radio waves, and thus helped found radio astronomy. It is particularly fitting that the same scientists, in their endless research on noise, should now battle this number-one enemy of telephony in the dramatic new field of communication via satellites. The ultimate goal, as always, is the improvement of your Bell System communications services.

BELL TELEPHONE LABORATORIES

WORLD CENTER OF COMMUNICATIONS RESEARCH AND DEVELOPMENT

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New refractory brick

A new refractory brick—*Korundal XD*—devised by Harbison-Walker Refractories Co. is said to have an unprecedented combination of improved physical properties and high-strength characteristics. In fact, the ability to withstand loading at high temperatures is so highly developed that special tests of long duration were devised for establishing its limiting properties.

This new mullite-bonded corundum brick withstands a 25-psi load at 3000°F for 100 hr with no dimensional change and exhibits no spalling at that temperature. Additional features of the new refractory are higher density and lower porosity. The new brick has already been used successfully in slab heating furnaces, enamel melting furnaces, and checker chambers. Other services projected for the new brick include: verticle lime kilns, vanadium-pentoxide furnaces, carbon-black furnaces, electric-furnace roofs, and tapping holes of iron blast furnaces.

Copper research

Research proposals totaling more than $132,000 as the initial phase of its 1961 program were announced recently by the Copper Products Development Assn. Organizations to receive contracts are: Armour Research Foundation, Applied Research Laboratory–University of Arizona, Battelle Memorial Institute, Franklin Institute Laboratories, Fulmer Research Institute, and Stanford Research Institute. The studies are designed to provide information on copper and its alloys and compounds that will be applicable to the development of new and improved copper products. Investigations to be made include: fundamental mechanism of the oxidation of copper, catalytic action of copper on internal combustion engines, potential new uses for copper in the electrical industry, copper catalysts for automobile afterburners, the effect of copper on the corrosion resistance of pearlitic cast iron, and the feasibility of anodic treatment of copper alloys.

Beryllium search intensified

Arizona, Nevada, Labrador, Alaska, Mexico, and possibly other areas of the North American continent will be the sites of extensive exploration for beryllium. This announcement was made to the N.Y. Society of Security Analysts by George A. Mikhalapov, president of Brush Beryllium Corp. Anaconda Co. also indicated that it would conduct extensive underground exploration at many beryllium claims on which it has options for two years.

Apparently, important cost reduction for beryllium metal is in the offing through new methods of ore concentrating and in the development of new fabrication and design application methods. Studies on pure beryllium production and possible fabrication are being conducted for the US Navy by the Franklin Institute in Philadelphia. Europe's only beryllium producer—Pechiney in France—is also engaged in investigating new production methods. (See p. 139 of this issue of JOURNAL OF METALS.)

Ductile iron engine blocks

Ductile iron may soon be competing vigorously with aluminum and gray iron as the major constituent in automobile engine blocks. A reliable source indicated that Ford is experimenting with ductile iron engine blocks and plans to use them on one of its 1962 models.

Although ductile iron is more expensive to produce than gray iron, its higher strength properties permit reductions in weight on the order of 30 pct. Machinability of ductile iron may also help to cut the machining costs now incurred in producing aluminum blocks which require ferrous inserts and liners. Also significant is the fact that Ford is one of the largest producers of ductile iron.

Other uses of ductile iron in the automotive field are appearing. Makers of automobile wheels are currently developing a combined wheel and break drum which would be cast as a single piece of ductile iron. Ford has been using ductile iron crankshafts for several years.

Nickel strip from powder

Metals for Electronics, Inc., of Hamden, Conn., has begun continuous rolling of strip from powder. The company recently established the first production unit for the direct compacting of powder. Output to date has been limited to nickel strip.

The purity of the strip compacted from powder limited only by the purity of the original powder. Finished strip is currently averaging 99.9 pct nickel, while carbon, sulfur, and oxygen contents are being held to extremely low levels.

Cryogenic alloy tested

Operation Cryogenics, a cooperative testing program among U. S. Steel, Chicago Bridge & Iron, and International Nickel, pointed out the superior properties of nine-nickel alloy containers for transporting and storing liquefied gases at temperatures as low as —320°F. The 9-pct Ni steel was evaluated because of its two basic advantages over other cryogenic materials presently employed: 1) lower production costs—since the alloy need not be stress-relieved after fabrication—and 2) greater strength in comparison with other materials which permits higher design stresses to be tolerated.

The test program had but one purpose —to demonstrate how tanks and full-size pressure vessels fabricated from the alloy would withstand impact shocks and extremely high pressures at low temperatures. Spokesmen for the participating companies were well satisfied with the performance of the alloy under test conditions.

With cryogenic applications expanding at a rapid pace, other steel producers are actively engaged in producing containers for liquefied gases. For example, Lukens Steel Co. recently produced its 500th hemispherical tank from the nine-nickel alloy. The 108-in. hemisphere is scheduled for application as a container for liquid oxygen.

REPORTER

Molybdenum oxide process

An acid process for the production of high-grade molybdenum oxide, used as an alloying agent in steel, was registered by the US Patent Office recently, with rights assigned to Kennecott Copper Corp. US Patent No. 2,965,447, *Acid Process for Production of High-Grade Molybdenum Oxide*, is a result of studies initiated in 1954 at Kennecott Research Center to produce high-grade molybdenum oxides from molybdenite (molybdenum sulfide) concentrates.

In the new Kennecott process, the molybdenite concentrates are roasted for partial elimination of sulfur, and the roasted product is dissolved with sulfuric acid at approx 700°F in a rotary furnace. The rotary furnace product is treated with water, and the solution is separated from the insoluble, worthless residue. The solution may be treated by an ion exchange extraction process or reacted with organic chemicals so that a high-purity molybdenum oxide can be recovered. This oxide can be further treated for the production of a high-purity molybdenum metal. The new process is said to be particularly suited to the treatment of lower grade molybdenite concentrates than can be treated by present processes.

ACAR direct reduction process

The ACAR process, or Allis-Chalmers Agglomeration-Reduction Process, for making pellets of reduced iron from high-grade iron oxide concentrates was announced recently by Allis-Chalmers Manufacturing Co., Milwaukee, Wis. In the new process, concentrates are first pelletized and dried. Then the pellets are pre-heated and reduced in a grate-kiln system (see p. 899 December 1960 JOURNAL OF METALS). The kiln itself is used as a gas cracker or reformer for preparing strong reducing gases, thus obviating the use of an external reducing gas generator. Carbon is presently added to the iron pellets to hasten reduction and increase the level of carbon in the reduced product, but it can be eliminated. The product obtained to date is about 95 pct reduced and non-pyrophoric. Pellets have been successfully melted in a hot-blast cupola with a metal recovery of 90 to 94 pct.

Zinc die cast alloy

New Jersey Zinc Co. announced the advent of a new zinc die cast alloy, which the company termed the first major improvement in zinc alloys in 30 years. The new alloy—*Zamak 7*—is expected to compete more keenly with aluminum and magnesium than present zinc alloys in use. It is claimed that the new alloy can boost production by cutting the rate of rejects, and at the same time, improve surface finishes. Another claimed attribute is that larger, more complex castings can be made with thinner wall sections. While the new alloy was developed with basically the same ingredients as two older zinc alloys—*Zamak 3* and *Zamak 5*—one element has been added and another has been reduced. A spokesman for the company foresees the day when *Zamak 7* will eventually replace the older alloys for zinc die casting purposes.

Continuous casting of steel

Following more than a decade of experimental and development work by BIRSA —the British Iron and Steel Research Assn.—industrial acceptance of the continuous casting of steel (see JOURNAL OF METALS, August and September, 1957) seems assured in Britain. This was brought to light recently in an editorial appearing in the Iron and Coal Trades Review. Today, Britain's plans for the continuous casting of steel are as ambitious as those of Russia. The Steel Company of Wales, Ltd., is installing the first commercial machine in the world for slab production by continuous casting of Bessemer steel. The company announced this in February. In April, the United Steel Companies, Ltd., announced that a 50,000 tons per year continuous casting plant was to be installed at its Appleby-Frodingham Works. And in August there was an announcement that Richard Thomas & Baldwins, Ltd., is to have a continuous casting plant for slabs in stainless and other qualities of steel.

The companies named are facing up to the fact that the process is vital to them if they are to retain and expand their export markets, for continuous casting gives at least a 7 pct reduction in production costs.

Venezuelan Al plant

Reynolds International Inc., has concluded an agreement with the Venezuelan government for the formation of a corporation which will build an aluminum reduction plant in the Caroni region of southeastern Venezuela. Completion of the $30-million project will mean the first production of primary aluminum in that country. Initial output will be approx 25,000 tons per year, the greater portion of which will be consumed in Venezuela. The contract provides for a 30 year power supply from the Caroni River hydroelectric project.

Largest EB furnace

As part of an expansion program, Temescal Metallurgical Corp. has moved its offices and plant from Richmond to Berkeley, Calif. to provide room for both current and long range programs.

A new electron beam furnace, the largest ever built, is under construction at the Berkeley site, and is expected to be in operation by mid-March. When completed, the furnace will stand three stories high and weigh about 25 tons. It will make possible the production of such refractory metals as zirconium, tungsten, titanium, cobalt and nickel alloys, and specialty steels.

Temescal is also planning to manufacture and sell electron beam furnaces for purposes other than casting and melting—such as preparation of specimens for high-temperature testing and other applications requiring high temperatures and vacuums.

At the same time, Stauffer-Temescal Co. —remaining at the Richmond, Calif., location—is changing its name to Stauffer Metals Co. Primary products of this firm are electron-beam processed refractory metals, custom electron-beam melting, and electron-beam melting and casting furnaces.

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Research in the metallurgy of the refractory metals tungsten, tantalium, molybdenum, columbium. Fundamental and applied research is carried on in the mechanical and physical properties of these metals, alloy development, protective coatings, and investigation of advanced processing and fabrication methods.

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personals

F. W. C. Boswell has been appointed associate professor in the Dept. of Physics, University of Waterloo, Waterloo, Ontario, Canada. He was formerly head of the metal physics section, Dept. of Mines and Technical Surveys, Ottawa, Canada.

Harry P. Croft has been elected a vice president of Copper Range Co., in charge of research and sales engineering. He was formerly with Chase Brass & Copper Co., and Kennecott Copper Corp.

John R. Daesen has been appointed technical director by the American Hot Dip Galvanizers Association, Inc. He is the author of the Galvanizing Handbook and the holder of patents on galvanizing and the casting and alloying of zinc, including the original patent on zinc-copper-titanium alloys.

Philip A. Gaebe has been appointed to the new position of product manager—refractories, for the refractories and chemicals div., Kaiser Aluminum & Chemical Sales, Inc.

Claus G. Goetzel has joined the Lockheed Missile and Space div., Research Department, as senior staff scientist. He will also lecture at Stanford University on powder metallurgy and on refractory metals. Dr. Goetzel was formerly a research professor at New York University.

E. A. March has been appointed director of technology by Crucible Steel Co. of America where he will be responsible for the direction of the technology department. He was formerly director of metallurgy and technical development.

Walter T. Haswell, Jr., works manager of Latrobe Steel Co., for the past five years, has been named vice president in charge of production.

Charles C. Hilton has been appointed superintendent, primary mills, at the Ecorse, Mich., plant of Great Lakes Steel Corp., a div. of National Steel Corp.

Herman J. Hofmann, service manager and in charge of advertising for the J. E. Baker Co., retired from the firm which he joined in 1944. He was previously with Lukens Steel Co., as assistant superintendent and later, superintendent of the open hearth department.

David M. Jacks has been named a vice president of Nalco Chemical Co. He will serve as an executive liaison officer, based in Chicago, and will coordinate administration of several of the company's subsidiaries and divisions.

James H. Keeler is now with General Electric Co.'s lamp metals and components department in Cleveland, Ohio. He was formerly at the company's Research Laboratory in Schenectady, N. Y.

A. J. Kiesler, a metallurgist at the General Electric Research Laboratory, has been chosen by the American Foundryman's Society to represent the US at the 28th International Foundry Congress in Vienna. Metallurgists from about 20 nations will attend the congress, scheduled for June 18-24. One paper will be presented by each nation. Mr. Kiesler's paper, *Desulphurization of Carbon Steel to Extra-Low Limits in the Basic Electric Furnace,* was selected as the official exchange paper from this country.

Orby Ray Sanders has been appointed to the staff of Union Carbide Nuclear Co.'s Oak Ridge Y-12 plant, an atomic energy installation. He was formerly with Carborundum Metals Co.

John D. Saussaman has been appointed assistant general superintendent, primary, at Kaiser Steel Corp.'s Fontana, Calif., plant. He was formerly assistant general superintendent, iron and steel div.

M. A. Scheil has been elected national secretary of the American Society for Metals. He will hold office through October 1962.

Ray J. Van Thyne has been appointed an assistant director of metals research at Armour Research Foundation. He is a specialist in high temperature alloys and the application of metals to special atomic energy problems.

Bruce Shields is now chief metallurgist at the South Works of U.S. Steel Corp. He was formerly at the Duquesne Works. **E. C. Rudolphy** is now assistant chief metallurgist at the South Works, and **Marshall W. Maxon** is chief metallurgist at the Duquesne Works. He was formerly assistant chief metallurgist at the South Works.

Arthur W. Thornton has been appointed director of engineering and research of U.S. Steel Corp's National Tube div. He was formerly general superintendent of the div.'s Lorain, Ohio plant.

Leonard P. Ziemkiewicz has been appointed supervising metallurgist, in the Melting, Metallurgical Laboratory, Quality Control Department, of Allegheny Ludlum Steel Corp.'s Brackenridge Works.

education

Ultrasonic Courses

The Nondestructive Testing Department of Curtiss-Wright Princeton div., will offer courses in Ultrasonic Inspection Techniques and Industrial Isotope Radiography at their Nondestructive Testing Laboratories in Princeton, N. J.

The course in Ultrasonic Inspection Techniques will be given from January 23-27, 1961. It will cover both contact and immersion ultrasonic inspection techniques. Special emphasis will be given to the inspection of welds, pipe, and tubing, and to new recording techniques.

The course in Industrial Isotope Radiography will be given January 30-February 3. It will cover selection, darkroom techniques, and instrumentation. The newest developments in shop and field testing equipment, including equipment using Cobalt 60 and Iridium 192, will be used as teaching aids and operated by students.

For further details, outline of the courses, and registration information, contact Bruce W. Smith, Curtiss-Wright Corp., Box 110, Princeton, N. J., SWinburne 9-0500.

Illinois Tech

A new x-ray diffraction laboratory, to be used for research and student instruction, is a recent addition to the metallurgical engineering department of Illinois Institute of Technology.

Used to determine the atomic structure of materials, the facility can serve as a means to forecast the strength and durability of various metals. Equipment of this type has also been utilized in uncovering the properties of materials and new methods to facilitate manufacture of intricate solid-state devices such as transistors.

The laboratory houses a microfocus unit and four basic X-ray units, two diffractometers, a single-crystal and a double-crystal spectrometer, various single crystal and power cameras, a liquid-nitrogen cryostat and miscellaneous auxiliary equipment.

Research currently in progress in the laboratory includes crystal structure analysis, absorption-edge fine structure, alloys formation, crystal perfection, crystal growth, and recrystallization studies.

Activities in the new laboratory are under the direction of Dr. Leonid V. Azaroff, associate professor in Illinois Tech's department of metallurgical engineering.

Literature

A pocket-size booklet on *Welding Metallurgy* has been published by the American Welding Society. A condensed textbook on ferrous and nonferrous welding metallurgy, the book contains 122 pages, 45 illustrations, 25 tables and 25 diagrams. The material is reprinted from the most recent edition of the Welding Handbook. Copies of the booklet are available at $2.00 each from AWS Information Center, 33 West 39th St., New York 18, N. Y.

The Electric Furnace Co., is offer-

(Continued on page 171)

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New Literature

THEORY OF METAL CUTTING

By Paul H. Black, Ohio University. 197 pages, $7.50.

An undergraduate text designed to provide the student with a theoretical and scientific understanding of the machining of metals. Consideration is given the cutting tool, the workpiece, the chip, and the cutting fluid. Discussions are included of solid-state physics as related to mechanical properties of materials, of the mechanics of the cutting process, lubrication and wear, and indications of how the developments can be utilized for the ultimate aim: increased production.

MECHANICAL BEHAVIOR OF MATERIALS AT ELEVATED TEMPERATURES

Edited by John E. Dorn, University of California, Berkeley. Ready in June, 1961.

A senior-graduate text and reference book containing a series of coordinated chapters by nationally recognized authorities on various aspects of the scientific basis and engineering application of the latest information on high temperature behavior of materials. The major intent of the book is to provide a systematic background for the scientist and engineer in dislocation theory and its application to creep and related high temperature properties.

INTRODUCTION TO SOLIDS

By Leonid V. Azaroff, Illinois Institute of Technology. 480 pages, $9.50.

An introductory text for students, advanced undergraduate and graduate, of chemistry, ceramics, metallurgy, mineralogy, physics, and all engineering fields dealing with solids. The book covers a somewhat larger variety of topics than have been previously encompassed in a single volume, but a deliberate attempt has been made to make most discussions complete and authoritative. Primary emphasis is on underlying principles; practical applications and specialized topics are omitted. The book concentrates on the structure, nature, and properties of inorganic crystalline solids.

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More information is given in the current report of INCO Laboratory activities, "Metals Plus Research." Do you want to review a copy?

Director of Research
The International Nickel Company, Inc.
67 Wall Street, New York 5, N. Y.

letters to the editor

Bulge Tester

Hydraulic Bulge Tester Determines Sheet Drawing Quality, JOURNAL OF METALS, November, 1960, p. 857.

Previous investigators have attempted to establish a single test to evaluate drawability, but without success. This lack of success only emphasizes the fact that drawability is not a single property, but depends on a combination of properties like those reflected by the parameters "n" and "R". Moreover, the particular combination of these properties that yields good performance depends upon the particular operation involved and thus can vary widely.

Any empirical or simulative test, such as the bulge test, can evaluate only a particular combination of those properties which influence drawability. Such a test should only be expected to give a good indication of drawing performance for those drawing operations which depend on approximately the same combination of properties that is evaluated by the test.

I seriously question the applicability of the bulge test (or any other single test) to provide a suitable measure of drawability over a broad range or drawing operations. One cannot ignore the fact that all drawing operations are not the same.

R. L. Whiteley
Supervisor
Mechanical Metallurgy
Bethlehem Steel Co.

* * *

85 W — 15 Mo

Taking note of the news release in the September issue of JOURNAL OF METALS relating to Climax Molybdenum's production of 85 pct Tungsten —15 pct Molybdenum ingots, I would like to bring to your attention the fact that Oregon Metallurgical Corp. developed this alloy, has been producing this alloy for eighteen months, and has made 11-in. diam ingots for one year.

We are also producing hollow centrifugal castings of this alloy 10-in. OD x 220 lb.

F. H. Vandenburgh,
Vice Pres. & Sales Mgr.,
Oregon Metallurgical Corp.

a new book

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Extractive and Physical Metallurgy of Plutonium and its Alloys

The Proceedings of a Technical Symposium sponsored by the Nuclear Metallurgy Committee of the Institute of Metals Division, and the Titanium, Uranium, and Uncommon Metals Committee of the Extractive Metallurgy Division, The Metallurgical Society of AIME. San Francisco, February 16-17, 1959.

Edited by W. D. WILKINSON,
Argonne National Laboratory

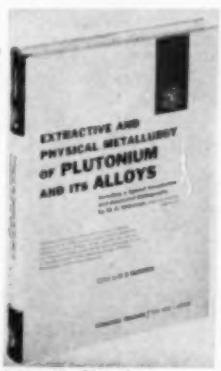
The addition to these Proceedings of an introductory chapter on the metallurgy of plutonium and of an extensive annotated bibliography has made this volume of even greater value to metallurgists working in this particularly important field. Mr. Wilkinson both edited the Proceedings and provided the new material.

CONTENTS

Introduction to Plutonium Metallurgy

EXTRACTIVE METALLURGY

- Alternative Routes for the Conversion of Plutonium Salts to Metal and Their Recovery Problems
- Calcium Reduction of Plutonium Halides to Metal
- Preparation of Metallic Plutonium
- Distribution of Plutonium and Selected Impurity Elements between Nitrate Solutions and Tri-n-butyl Phosphate
- The Preparation of Plutonium Halides for Fused Salt Studies
- Removal of Fission Product Elements from Plutonium by Liquidation



PHYSICAL METALLURGY

- Some Principles of the Alloying Behavior of Plutonium
- The Plutonium-Cerium Diagram
- Plutonium-Zinc Phase Diagram
- Metallography of Alpha Plutonium
- The Etching of Plutonium and Its Alloys by Cathodic Bombardment
- A Study of the Transformation Kinetics of Alpha, Beta, and Gamma Plutonium
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editorial

IMPROVING COMMUNICATIONS

For some time the need has been apparent for improved communication between the military on the one hand and the scientific fraternity on the other. Many scientists and engineers, not actively engaged in research on matters of interest to the military, have little conception of the breadth of the Defense Department's programs or the nature of many of the problems being studied. Military personnel have wished for better means of acquainting these scientists and engineers with the military program so that they would be in a position to bring discoveries to the attention of the Government.

With this in mind the Institute of Metals Division of The Metallurgical Society set about providing a medium of communication between the military and metal scientists and engineers—a forum in which the various military research programs could be outlined and particular areas described in detail—a platform upon which the military could stress areas of current research interest and avenues of future metallurgical research and development programs. This has taken the shape of three all-day symposia.

The first of these was *Metallurgy in the Navy* presented at the 1960 AIME Annual Meeting; the second was *Metallurgy in the Army* presented at the 1960 Fall Meeting; and the final symposia, *Metallurgy in the Air Force* is scheduled for the 1961 Annual Meeting.

Sensing the importance of these symposia as a communications *breakthrough* (to use our favorite word), the JOURNAL OF METALS published papers from the Navy symposium in the August and December 1960 issues. In this issue we would call your attention to articles pertaining to the Army symposium, and it is our expectation to publish articles from the Air Force symposium in a future issue.

The importance of the Defense Department's metallurgical research and development effort cannot be over-emphasized. The future of our Nation, as well as our way of life, may depend upon it. We would, therefore, ask you, our readers, to pay particular attention to these articles as they appear within our pages. FWS

AIME President, 1961 — *R. R. McNaughton*

Ronald Russel McNaughton, manager of the Metallurgical div., of The Consolidated Mining and Smelting Co. of Canada, Ltd., is the 1961 President of AIME. He succeeds Joseph L. Gillson, who recently retired as chief geologist for The Du Pont Co.

The first Canadian ever to be elected president of AIME, Mr. McNaughton has been active in the Institute for many years. He has served as a Director of The Metallurgical Society from the Extractive Metallurgy Division. He was chairman of EMD in 1953 and was a director of AIME in 1953 and 1954.

Born in Vancouver, B. C., Canada, Mr. McNaughton attended the University of British Columbia and was an honor graduate of McGill University in 1923 with a Bachelor of Science degree in metallurgical engineering.

He joined Consolidated Mining and Smelting in 1924 and is still with the company—one of the world's largest producers of lead, zinc, silver, and chemical fertilizers. Metal output also includes cadmium, bismuth, gold, indium, antimonial lead, and tin.

Beginning as an assayer, he served in the Smelting Department successively as assistant foreman, development engineer, assistant superintendent, and metallurgist. He was in charge of research and development on a number of projects in the smelting department, including the slag fuming plant which was constructed in 1930, and remains as the largest unit of its kind.

After serving as chief metallurgist, he was appointed manager of the Metallurgical div. in 1946. His present responsibilities include the reduction and refining of all metal products and involve the employment of some 1800 people.

In addition to AIME and The Metallurgical Society, Mr. McNaughton is a member of the Association of Professional Engineers of the Province of British Columbia and the Canadian Institute of Mining and Metallurgy.

Although Mr. McNaughton's interests are mainly centered on his professional associations, he finds time in the summer months to play golf, his favorite recreational activity. In his younger days he was a better-than-average violinist, and as a bachelor in the first few years he was at Trail, he formed part of a *bunkhouse orchestra* that served to brighten off-hours.

Mr. McNaughton is married to the former Dorothy Millen of Montreal, and has two married sons, Richard and Peter.

J. Stuart Smart, Jr. Metallurgical Society President, 1961

J. S. Smart, Jr., general sales manager of American Smelting and Refining Co., is the 1961 President of The Metallurgical Society. He will take office February 28 at the Annual Meeting in St. Louis.

Mr. Smart received a bachelor of science degree from the University of Michigan. He gained his early experience with the Ford Motor Co. and Detroit Lubricator Co. before affiliating with American Smelting & Refining Co. as a research metallurgist in 1936. He assumed his present position in 1958.

Active in AIME for many years, Mr. Smart was a Director in 1955. He was chairman of the AIME Rossiter W. Raymond Award Committee in 1954. In 1948 he received the Institute of Metals Division Award, now the Mathewson Gold Medal Award. He also served a three-year term, ending in 1961, as a director from the Institute of Metals Division.

Copper metallurgy and continuous casting have been among Mr. Smart's main interests. He was the innovator of several patented continuous casting processes. He is internationally distinguished as an authority on the properties and treatment of copper.

In addition to his activities in AIME, Mr. Smart is also a member of the Industry Development Committee and a member of the Board of Directors of the American Zinc Institute; a member of the Technical Committee of the Copper Products Development Association; and a member of the Industry Development Committee of the Lead Industries Association.

Mr. Smart is married to the former Lily Hindley, and has three children.

Division Chairmen of The Metallurgical Society

ISD

Gerhard Derge

Dr. Gerhard Derge, Jones and Laughlin Professor of Metallurgy at the Carnegie Institute of Technology, is the editor of the TRANSACTIONS OF THE METALLURGICAL SOCIETY OF AIME.

Dr. Derge received his education at Amherst and at Princeton, where he received his PhD in 1934. He holds a Phi Beta Kappa key and also belongs to Sigma Xi. From Princeton he went to the Metals Research Laboratory at Carnegie Tech where he was, in 1951, the first person appointed to the newly created Jones and Laughlin professorship.

Elected to the Institute in 1934, Dr. Derge has been active for many years on technical and publications committees of the Iron and Steel Division. He also served as a member of the former Technical Publications Committee. He has written over 70 technical papers which have been published in various journals. He has served on AIME's Physical Chemistry of Steelmaking Committee, the Physical Chemistry of Extractive Metallurgy Committee, the ISD Executive Committee, and the Electric Furnace Conference Committee. He has also served as chairman of ISD's Publications Committee and the Program Committee. In 1952, Dr. Derge received the Robert W. Hunt Award for the best original paper on iron and steel. His special field of interest has been in the physical chemistry of blast-furnace ironmaking and open-hearth and bessemer steelmaking.

EMD

Richard C. Cole

Richard C. Cole is vice president in charge of manufacturing for Vitro Chemical Co., and a vice president of Vitro Minerals Corp. He holds a bachelor of science degree in metallurgical engineering from the University of Washington.

Before joining Vitro, Mr. Cole served 20 years with American Smelting & Refining Co. He joined Vitro Corp. of America in May of 1954 as manager of Vitro Uranium Co.'s uranium processing plant in Salt Lake City. He was named vice president of the uranium company in 1957 and president in 1959, the same year he became vice president of Vitro Minerals. In October 1959, Vitro Uranium was made a part of the newly formed Vitro Chemical Co., and Mr. Cole became vice president of the new firm.

IMD

J. Harry Jackson

J. Harry Jackson is manager of Battelle Memorial Institute's Department of Metallurgy, which comprises ten major research divisions. A top-ranking metallurgist in his own right, Mr. Jackson has had many years of experience as a research administrator.

With many metallurgical interests, Mr. Jackson has made important contributions to foundry practice, to the development of titanium, magnesium, and beryllium alloys, to the development of improved alloys for many applications, and to the heat treatment, working, and fabrication of metals and alloys. He is the author of numerous technical papers and holds several patents in ferrous and nonferrous metallurgy. A graduate of Rensselaer Polytechnic Institute, he has been a member of the Battelle staff since 1941.

Mr. Jackson has been Executive Vice Chairman of the Institute of Metals Division; Program Chairman of The Metallurgical Society; Chairman of DOD Standing Review Committee of Materials Advisory Board (National Academy of Science) on Metallic Materials; a Member of Materials Consultant Panel on Aircraft Nuclear Propulsion Program; and a Past Chairman of the Columbus, Ohio, chapter of the American Society for Metals.

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Properties of Elemental and Compound Semiconductors

5 Sponsored by the Semiconductors Committee of the Institute of Metals Division, The Metallurgical Society, and the Boston Section of AIME. Boston, August 31-September 2, 1959

Edited by Harry C. Gatos

Contents

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Proceedings of the 1960 Conference, Metallurgy of Elemental and Compound Semiconductors Boston, August 29-31, in preparation

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Proceedings of the Second Technical Conference Sponsored by the Mechanical Working Committee of the Iron and Steel Division, The Metallurgical Society and the Chicago Section of AIME, Chicago, January 20, 1960

Edited by E. W. Earhart and R. D. Hindson

Contents

Hot Machine Scarfing of Semi-Finished Carbon Steels
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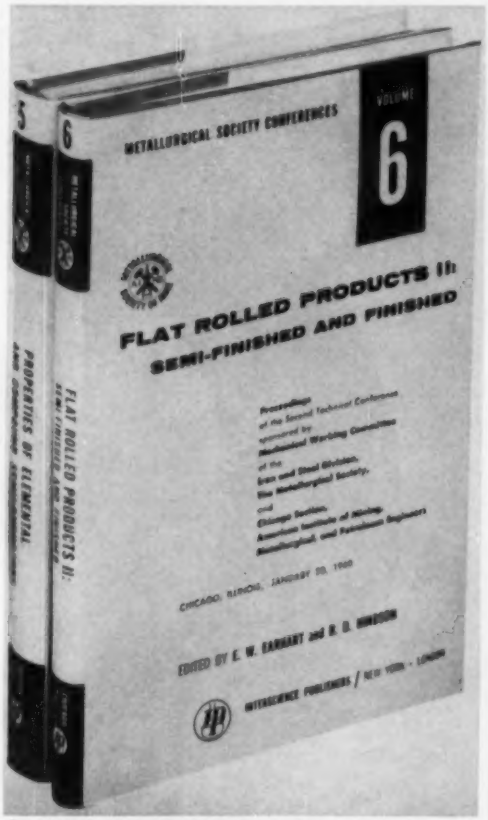

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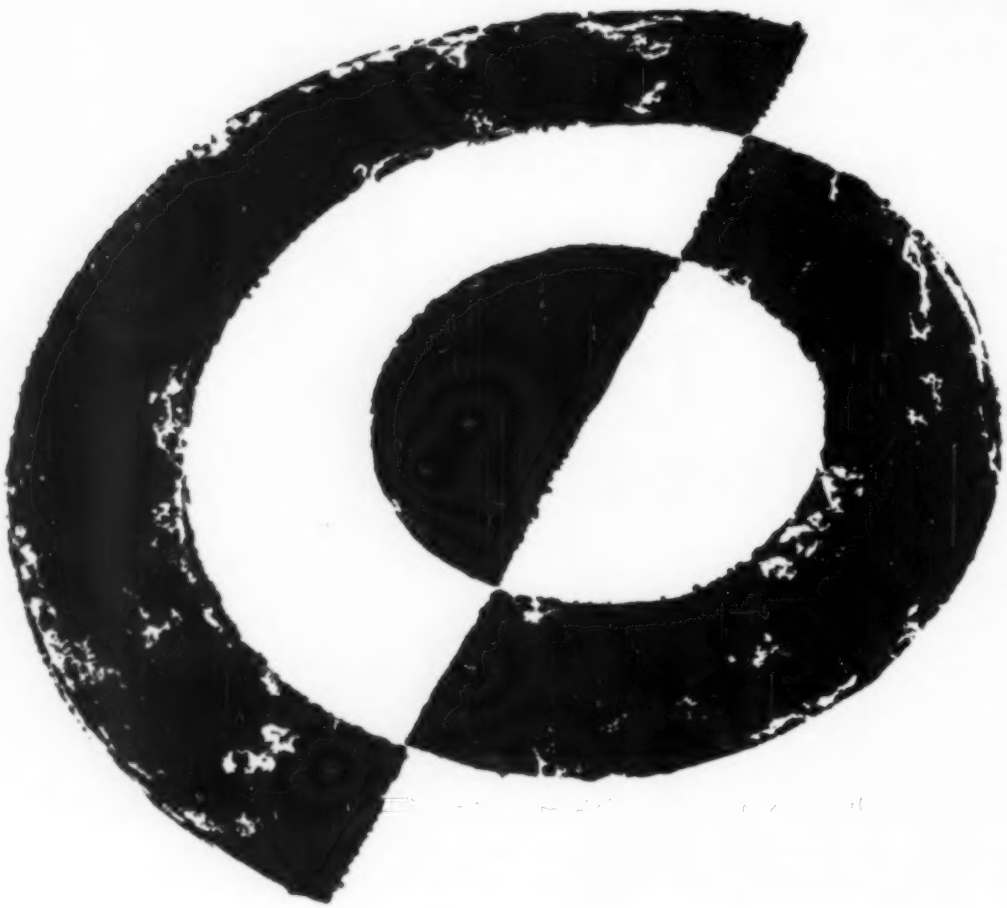

Said J. Stefan and L. Boltzmann: *"The total radiation from a black body is proportional to the fourth power of the absolute temperature of the black body."*

Radiation is usually associated with high temperatures. Yet very cold bodies emit a radiation which can be highly significant in missile and space applications. The problem faced by infrared scientists, trying to detect variations in radiation from low temperature atmospheres, can be likened to detecting a one-foot cube of ice from a distance of five miles.

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METALLURGY IN THE ARMY

Metallurgy in the Army—Requirements, Application, and Research was the topic of an all-day session at the Fall Meeting of The Metallurgical Society at the Sheraton Hotel in Philadelphia on October 17.

Featured speaker at the noon luncheon was J. R. Townsend, Special Assistant to the Director of Defense Research and Engineering, and president of the American Standards Assn. Mr. Townsend spoke on *The Role of Metals in National Defense* in which he related the important roles that metals have played in past history and emphasized the importance of metals today. In the past 15 years, metallurgy has grown rapidly, and indications are that its importance will increase even more as a result of the demands of the space age. National Defense has created some new roles for metals. Experience gained in World War II and the Korean conflict indicated that new, *special* materials were necessary for defense, and because of their *importance*, accelerated research programs were carried out. The titanium program, in which this vital metal was brought from the laboratory to extensive engineering usage in five short years, is an excellent illustration of rapid developments brought about by the urgency of National Defense. Extensive use of heat-resistant refractory metals in missiles has resulted in the development of fabrication methods unheard of several years ago. These accelerated research programs, although expedient, have been devoted largely to specific development projects rather than to studying the basic theoretical properties of materials.

To overcome the deficiency in our knowledge of basic theory, the US Department of Defense is fostering fundamental research by supporting, through the use of funds under the jurisdiction of the Advanced Research Projects Agency, a scheme whereby a number of universities have been selected to do fundamental research in materials science. The program provides for the establishment of inter-disciplinary laboratories in order to investigate the following suggested areas:

1) Phenomena related to high-temperature behavior of systems involving gases,
2) Energy conversion as related to materials,
3) Extreme temperature properties of solids,
4) Basic properties of fibers and films,
5) Failure-producing phenomena,
6) Experimental techniques,
7) Fundamental surface phenomena,
8) Structure of solids,
9) Methods of synthesis of new materials,
10) Theory of the behavior of materials,
11) Interaction of radiation and matter,
12) Effects of trace impurities, and
13) Basic research relative to extractive and process metallurgy.

The need for information of an engineering character has brought about the establishment of information centers, such as the one for titanium at Battelle Memorial Institute. More of these technical evaluation centers are either in the planning stage or are now operating.

Thus, the needs of National Defense have stimulated the rapid growth of metallurgy over the past few years, and ever-increasing demands will intensify this growth in the future.

R&D—Shield for the Future was the title of a talk presented by Brig. Gen. William J. Ely for Lt. Gen. Arthur G. Trudeau, chief of research and development, Dept. of the Army. Our ability, as a Nation, to compete in the world market—or on unforeseen battlefields—in the 1960's or 70's will be determined by the scientific progress now underway in our country. Emphasis is being placed on fundamental research and particularly on materials sciences. Metallurgical approaches, now under consideration,

are designed to develop materials for specific end items, to decrease weight requirements on all weapons and equipment, to develop metals that can withstand extreme environmental conditions, to improve processes such as high energy rate forming, to create substitutes for potentially critical materials, and to encourage and procure men trained in metallurgy.

He concluded, "There is a clear call today which bids us all to guard and defend the ark of our national covenant—a call that sounds the warning—that time is of the essence and that faith, nor fear, and courage, not complacency, are the keys to our survival."

Brig. Gen. William J. Ely, director, Army Research Office, presented the broad aspects of the Army's research program, which encompasses all of the major scientific disciplines at a cost of $170-million annually with about $50-million of the total directed toward basic research. More than 2600 research tasks are currently in progress at Army installations, Government agencies, industrial organizations, and universities on a 40 pct in-house and 60 pct outside basis all over the world.

Coordination with the Navy and Air Force is maintained through joint service operations such as ASTIA—Armed Forces Technical Information Agency—the co-sponsoring of inter-service research programs, and the use of other Government agencies.

Presently, 2000 officers who are qualified as scientists and engineers, approx. 21,500 Civil Service employees, some 1500 enlisted technicians, and numerous contract scientists and engineers make up the Army's research organization.

Papers presented at the symposium illustrated the various projects under way in the Army's research and development program.

Requirements of new equipment was discussed by C. B. Salter, US Army Ordnance Tank—Automotive Command, in his paper on *Combat and Tactical Vehicles*. Versatility, the prime factor in vehicles, has imposed many metallurgical problems. Lighter, higher-strength materials are a must, and the materials must also exhibit good resistance to environmental conditions; however, these properties often conflict. Magnesium-lithium-aluminum alloys are under investigation in this area, and development work is being carried out in the fabrication of these alloys. In addition to metals, plastics and fiber glass are under consideration.

Communications by S. B. Levin, US Army Signal Corps, indicated that the military was beginning a new era of communications. Just as communications systems of today are a far cry from the semaphore system used not too long ago, tomorrow's systems will be even further advanced. New systems will require enhanced reliability properties, increased range and capacity, more miniturization, greater environmental resistance, and lower maintenance and production costs. Research and development work ranges from insulators through semiconductors to superconductors; applicability for magnetic, dielectric, ferroelectric, piezoelectric, and optical materials; and the custom tailoring of exploitable properties. Challenging areas include: compound semiconductors, thermionic emission, surface, phenomena, refinement of bulk properties, and transient effects of radiation. Thus, communications provide a universe of challenges to the metallurgist.

Space Age problems were discussed by J. L. McDaniel, technical director, research and development operations US Army Ballistic Missile Agency, in his paper *Solid-Propellant Rocket Motors*. Improvement of performance of solid-propellant rockets depends to a great extent on the properties and characteristics of the inert parts of the motor. Materials having a high strength-to-weight ratio are of vital importance in increasing rocket efficiency; therefore, low-density, high-strength materials are undergoing extensive development work. The use of titanium vs steel in motor components is typical of the results of these programs. Further investigations are being made of materials exhibiting good heat and corrosion resistance properties. In addition, materials employed in rocket motors must be readily *fabricable*, and work is being done in this area.

Point Defects in Pure Nickel by J. J. Antal and Allen Goland, Materials Research Laboratory, Ordnance Materials Research Office, illustrated the basic research being undertaken by the Army. The paper was concerned with the crystallographic defects having dimensions on the order of one to several atoms in nickel. Defects, introduced during crystal growth, or by mechanical working, were studied by scattering very low energy neutrons through the crystal structure. The results were correlated with stored energy and resistivity measurements.

Continuing with more basic research, *The Role of Dilute Binary Transition Element Solutes and Time on the Recrystallization of Iron* was presented by E. P. Abrahamson II, Watertown Arsenal Laboratories. Investigations showed that all of the elements immediately increased the recrystallization temperature, with the majority having their greatest effect in amounts of less than 0.10 at pct. Varying time from 20 to 4000 min merely shifted the recrystallation vs at pct solute curve without changing the slope of its initial linear portion. Correlation was noted between the rate of change of recrystallization, as well as the recrystallization activation energy with at pct solute, and the ground state outer electron configuration of the solute element.

Chemical reactions and phase transformations under very high temperature and pressure conditions were presented by A. A. Giardini and J. E. Tydings, US Army Signal Research and Development Laboratory, in *Metallographic Investigation of a Multistage Piston Assembly Used in a Very High Pressure-High Temperature Apparatus*. The effects of mechanical and thermal stress upon microstructure, and macrostructural stress-strain relationships were investigated. Static pressures as high as 1,200,000 psi with coincident temperatures of approx 2000°C were attained during the tests. Among the components tested were thin copper sheets used as stress homogenizers between the piston components, thin nickel disks used as electrical contacts, platinum tubes used as specimen capsules and electrical resistance heaters, and thin-walled steel sleeves used as cylinder liners within the pressure apparatus. Design principles, operational requirements, and operational problems in pressure instrumentation were also included in the paper.

Of the papers presented, the following—*Metallurgical R&D in The Army* by Lt. Col. L. G. Klinker, and *Light Armor Materials* by H. P. George—were considered to be of particular interest to the members of The Metallurgical Society.

EJF

I. Metallurgical R&D in the Army

Persons not familiar with the organization of the Army's research and development programs often experience communication difficulties when trying to exchange information. Therefore, this paper is intended to provide some information on the organizational set-up employed for metallurgical research and development projects.

by L. G. Klinker

No Army operation could be planned or executed without giving consideration to the products of the metallurgical industry; therefore, over 30 US Army laboratories, offices, and agencies, are closely associated with metallurgical research and development on either an *in-house* or contract basis. More than 100 metallurgists, approx 60 pct civilian, monitor specific metals research programs approaching $4-million annually.

Since the Army's research and development program is so vast and complicated, a decentralized laboratory and arsenal system is ideally suited for its management. Such decentralization does not preclude a knowledgeable central monitor, and it does not preclude overall program response to suggestions of lower, higher, or parallel advisory bodies. It also does not destroy the ability to coordinate actions either vertically or horizontally.

When decentralization exists, persons not familiar with our management philosophy experience some communication difficulties. It is for this reason that the Army would like to present to representatives of the academic and industrial metallurgical field a *feel* as to who does what and why in the Army's metallurgical research and development programs.

In the Washington, D. C. area, the Department of the Army is concerned with top-level planning and guidance of the programs. Army-wide information, budgetting, programming and guidance in the field rests with the Army Research Office (ARO). As can be seen in the schematic diagram, Fig. 1, this office works closely with the various headquarters of the technical services illustrated. ARO attempts to make industrial, academic, and private research institutes aware of the Army's needs and activities by briefings, answering individual requests, and by providing literature. For example, the following brochures are available from ARO: Scientific Research Grants, a Contractor's Guide, and a Problems Guide. In addition, the Army Research Task Summaries has been arranged for sale through the Office of Technical Services, Dept. of Commerce. This latter document—Army Research Task Summaries, Vol. 6—is particularly important to the metallurgist. It outlines the who, what, and where of all unclassified metallurgical research and development. Also available are auxiliary volumes on engineering, physics, and chemistry.

Ordnance Corps

The largest activity by far, is conducted by the US Army Ordnance Corps. Its metallurgical research and development work can be divided into three categories: basic or fundamental research, supporting research, and applied research.

Fundamental research: Fig. 2 indicates where most of the basic research in metallurgy is carried out. The type of work supported by these various groups stems from unsolicited proposals emanating primarily from the academic world. Contact point for metallurgists is the Metallurgical Sciences div. of the US Army Office of Ordnance Research (OOR) at Durham, N. C. Support of solid state, mechanical, and thermal metallurgy is pursued by contracts or grants in fields of Ordnance interest, and significant allied activities are supported by OOR's Chemical and Physical Sciences divisions. Basic and fundamental work on interatomic bonding energies, electronic structures, impurities, structural imperfections, mechanical properties of solids, and radiation and shielding studies is performed at the Materials Research Laboratory (OMRO). In addition to performing the research tasks, OMRO also monitors all Ordnance supporting metallurgical research.

Supporting research: Fig. 3 illustrates the various arsenals at which supporting activities take place. The following activities are typical for the installations listed:

1) Watertown Arsenal laboratories are primarily concerned with graphite and ceramics, ballistic and radiological armor, non-destructive testing, high-temperature materials, ferrous metals, titanium and special metals, physical and mechanical testing, welding, applied mechanics, and chemical metallurgy;

2) Rock Island Arsenal laboratory works principally with metal surface coatings;

3) Frankford Arsenal research and engineering div. covers nonferrous metals, electroplating, nonferrous armor welding, corrosion, powder metallurgy, and non-destructive testing;

4) Picatinny Arsenal plastics and packaging laboratory is involved in metal applications for the packaging operation; and

5) Springfield Armory research laboratories work exclusively on columbium.

At Aberdeen Proving Ground, the metallurgical problems of interior, exterior, and terminal ballistics are explored in the Ballistics Research laboratories; the development and proof services are primarily concerned with armor testing; and the coating and chemical laboratory works on paints, cleaners, finishers, hydraulic fluids, anti-freezes and their attendant metallurgical problems. OMRO supervises the Ordnance Tank-Automotive Com-

L. G. KLINKER, Lt. Col. US Army, is with the Chemical and Materials Branch, Physical Sciences div., Army Research Office. This paper was presented at the 1960 Fall Meeting of The Metallurgical Society.

mand's armor and non-destructive testing programs performed both in-house at Detroit Arsenal and outside under contract.

Applied research: Work in this area is directed toward the solution of specific problems deriving from end items. The commands involved in applied research are:

1) Tank-Automotive Command—the Detroit Arsenal acts as its technical center;

2) Special Weapons and Ammunition Command—Picatinny Arsenal is its principal laboratory support;

3) Weapons Command—Rock Island, Springfield, and Watertown Arsenals all lend their support to this command; and

4) Missiles Command—Ordnance Missile Laboratories and Redstone Arsenal act as technical centers for the operations.

Certain laboratories and arsenals also have prime responsibilities for end items but do not have command status. This requires them to perform both supporting and applied research tasks.

Signal Corps

The second technical service with major metallurgical problems is the Signal Corps. Of the five basic departments in the Signal Research and Development Laboratory, the work of most interest to metallurgists is concentrated in two: the Institute for Exploratory Research and the Electronic Components Research Dept.—illustrated in Fig. 4.

The Institute for Exploratory Research consists of four divisions: S, C, E, and Mathematics. The

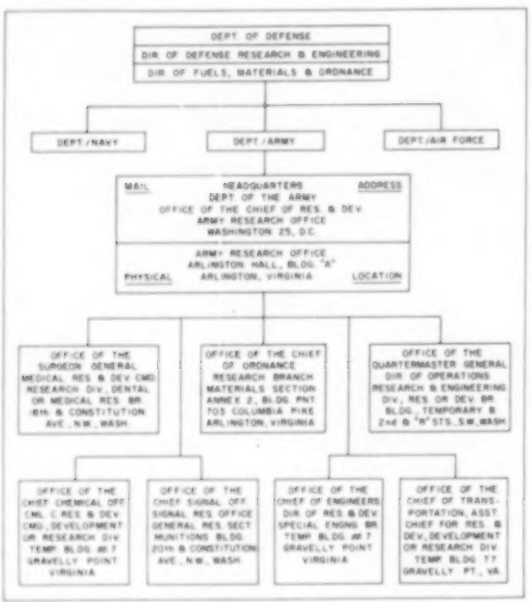


Fig. 1—The Army Research Office and headquarters of the various technical services.*

U.S. ARMY ORDNANCE CORPS
BASIC & FUNDAMENTAL RESEARCH
— MATERIALS —
COVERAGE: BASIC & FUNDAMENTAL RESEARCH IN PHYSICS, CHEMISTRY, METALLURGY & NUCLEONICS DIRECTED TOWARD NEW OR IMPROVED MATERIALS. UNSOLICITED PROPOSALS FROM RESEARCH WORKERS ARE PURSUED IN FIELDS OF ORDNANCE INTEREST.
OFFICE OF ORDNANCE RESEARCH (OOR)
BOX CM DUKE STATION
DURHAM, N.C.
DR. J. W. DAWSON
CHIEF SCIENTIST
ORDNANCE MATERIALS RESEARCH OFFICE (OMRO)
WATERTOWN ARSENAL
WATERTOWN 72, MASS.
DR. J. L. MARTIN
DIRECTOR
MATERIALS RESEARCH LABORATORY (OMRO - MRL)
DR. R. BEEUWKES JR.
CHIEF SCIENTIST
WATERTOWN 72, MASS.

Fig. 2—Organization of basic metallurgical research within the Army Ordnance Corps.*

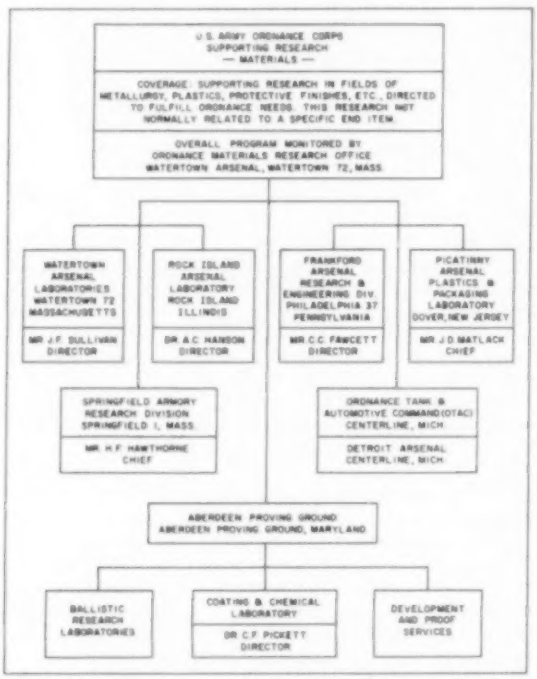


Fig. 3—Supporting research activities of the Army Ordnance Corps.

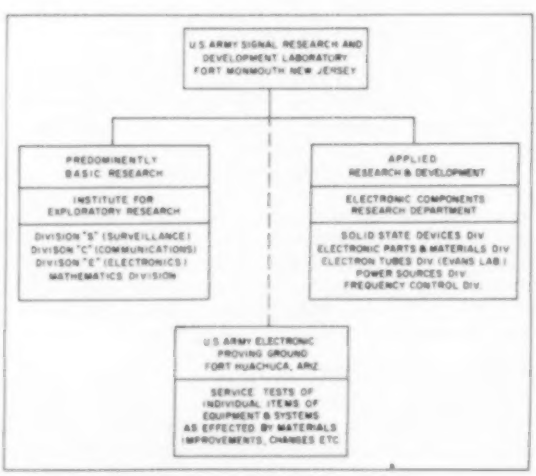

U.S. ARMY SIGNAL RESEARCH AND DEVELOPMENT LABORATORY
FORT MONMOUTH, NEW JERSEY
PREDOMINENTLY BASIC RESEARCH
INSTITUTE FOR EXPLORATORY RESEARCH
DIVISION "S" (SURVEILLANCE)
DIVISON "C" (COMMUNICATIONS)
DIVISON "E" (ELECTRONICS)
MATHEMATICS DIVISION
APPLIED RESEARCH & DEVELOPMENT
ELECTRONIC COMPONENTS RESEARCH DEPARTMENT
SOLID STATE DEVICES DIV.
ELECTRONIC PARTS & MATERIALS DIV.
ELECTRON TUBES DIV. (EVANS LAB.)
POWER SOURCES DIV.
FREQUENCY CONTROL DIV.
U.S. ARMY ELECTRONIC PROVING GROUND
FORT HUACHUCA, ARIZ.
SERVICE TESTS OF INDIVIDUAL ITEMS OF EQUIPMENT & SYSTEMS AS EFFECTED BY MATERIALS IMPROVEMENTS, CHANGES ETC.

Fig. 4—Metallurgical research within the Signal Corps.

first three divisions correspond to long range programs in surveillance, communications, and electronics respectively, and are involved in metallurgical research. These divisions are currently involved in studies on cryogenics and super conductivity, crystal growth, crystallography, and crystal structure. Also included are fundamental properties of crystalline solids, including conductors, semiconductors, dielectrics, ferro-electrics, magnetic oxides, and thermoelectrics.

The Electronic Components Research consists of five divisions, all of which are involved in metallurgical research. Typical of the fields under consideration are: solid state devices—solar cells, thermoelectrics, transistors, diodes, etc.; electronic parts and materials—applied research in magnetic, dielectric, thin films, and radiation studies; electron tubes—glass-metal seals, tube structures, and metal oxides for cathodes; power sources—fuel cell metallurgy, and thermionic conversion; and frequency control—piezoelectric crystal, and metals for filter applications, etc.

Other technical services

Space does not permit a detailed description of the projects of the other five technical services. Most of these services are currently concerned with application of metals to their end items. ARO will provide guidance to interested individuals or organizations as to exactly the who, what, and where of these projects. The Contractor's Guide and the Problems Guide will also aid in locating the metallurgical research and development of these services.

International research program

In addition to the many contacts awarded in the US, the Army has contracts with scientists and research organizations throughout the world. Such well known European organizations as Fulmer Research in England, SINTEF in Norway, Instituto de la Soldadura in Spain, and the French CNR Ferromagnetic Laboratory are all holders of modest metallurgical contracts.

The Army has a sense of urgency in its efforts. We want to use every facility at our command to build the items that make our soldiers have the highest firepower, the best communications, and the greatest mobility of any fighting man on earth.

In order to accomplish its task, the Army will continue to place emphasis on the creative scientist and engineer, and attempt to keep him well informed so that his contributions will be rapidly reflected in better and lower cost equipment.

* As we went to press, it was announced that the Office of Ordnance Research was transferred to the command of the Chief of Research and Development of the Department of the Army. The Office of Ordnance Research has been redesignated, Army Research Office-Durham. It is not anticipated that the activities of the Office of Ordnance Research, with respect to the Ordnance Corps, will be materially changed. But the range of activities of Army Research Office-Durham will be increased to serve better the interests of the other technical services and the Army as a whole. This newly-designated office will become the primary point of contact in the Department of the Army for basic research in the physical sciences.

II. Light Armor Materials

In order to increase the mobility of its combat vehicles, the Army is declaring war on all heavy materials. This paper investigates the possibilities of various armor materials, explains how they are evaluated, and presents results of these evaluations.

by H. P. George

New concepts of mobile striking forces and the employment of these forces for the rapid envelopment of strategic enemy strong points have necessitated the development of optimum armor for mobile vehicles. If the occasion for their use arises, men, equipment, and vehicles will be parachuted on lightly defended terrain near a critical target and advance to attack with the greatest possible speed.

The selection of the armor material for any combat vehicle represents a compromise between the desired protection and mobility. Increased protection obtained by increase in armor weight reduces mobility, maneuverability, and operational range. In air-drop operations, a serious penalty is paid for any superfluous pound carried. Thus, it is imperative to develop and evaluate armor materials which provide maximum protection per unit weight.

H. P. GEORGE is with the Pitman-Dunn Laboratories, Frankford Arsenal, Philadelphia, Pa. This paper was presented at the 1960 Fall Meeting of The Metallurgical Society.

It is not possible to select an armor material entirely on ballistic performance, since there are certain structural and manufacturing requirements which have to be considered. Armed with ballistic and engineering data on armor materials, the designer must select the material and configuration which best meet the prescribed requirements within the allowable design weight.

In this presentation, quantitive graphs will be avoided, and only graphs which are considered typical of the most critical conditions anticipated in service will be presented.

Military requirements

An assessment of the casualties to infantrymen in World War II and the Korean Conflict, indicated that the largest single cause of death and disablement was from fragments of high-explosive shells and mortars. A typical distribution of fragments from a wrought steel shell ranges in size from dust-like particles to angular, jagged masses weighing as much as 1500 grains (3 oz.) The small particles

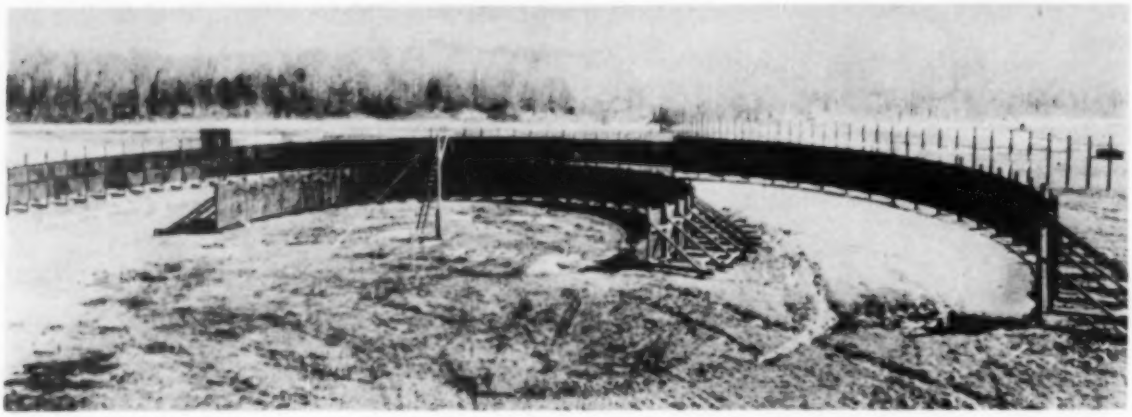


Fig. 1—Above, Yankee Stadium test set-up. Fig. 2—Below, Protection afforded by weldable aluminum and standard armor steel against shell fragments.

lose velocity rapidly because of air drag, but the higher-mass particles have considerable capacity for inflicting casualties at substantial distances from the detonation center. Thus, fragment protection is a prime military requirement for armor materials.

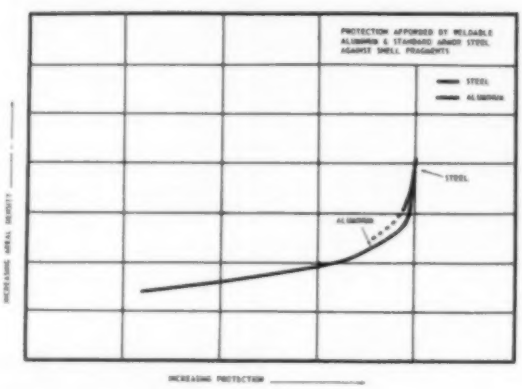
It is also considered essential that the armor should offer a high order of protection against small arms rifle and machine gun fire. The mose destructive round of this type is the armor-piercing projectile. In addition to these requirements, it is important to provide as much protection as possible from the blast action of anti-personnel mines, and from *near misses* of high-explosive shells.

Structural requirements

In addition to the military criteria, there are other requirements which must be met.

Weldability of the material is important because welding is the accepted procedure for the assembly of armor plate into hull structures for at least two major reasons. First, the vehicles are expected to operate amphibiously; therefore, water-tight joints are a necessity. And secondly, welding is, in general, more economical than mechanical assembly. It is, thus, essential that all armor material be capable of being welded by techniques readily adaptable to industrial shop procedures. It is also important that the materials possess reasonable machinability and formability to falicitate cutting, shaping, and fitting of plate prior to assembly.

Any armor material must retain its mechanical and ballistic properties after protracted exposure at extreme temperatures anticipated in Ordnance service— −60° to 165°F—and must be resistant to environmental corrosion. The resistance to corrosion should include the absence of any dangerous sensitivity to stress corrosion.



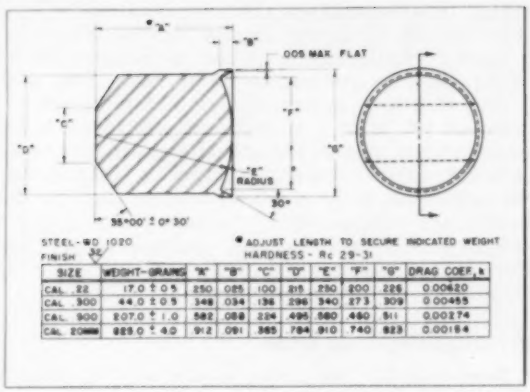
Basic materials as-assembled must be strong enough to resist service stresses including the shock encountered in air-drop and cross-country operations. Density and modulus of elasticity are important in relation to the thickness and stiffness of the sections. All factors being equal, low density is undesirable because it increases the required section thickness, thus consuming valuable space and increasing the amount of weld metal in the joints. However, since stiffness is a cubed function of the modulus of elasticity and section thickness, it follows that armor hulls prepared from light alloys have proved to be more rigid. In addition to these factors, it is apparent that any material selected must be plentifully available at a reasonable cost.

Material selection and evaluation

In some instances, the criteria listed have been used as a basis for selecting specific alloy materials, but in other cases, it has been necessary to parallel

Table I. Some Properties of Armor Materials

Base Material	Type	Major Alloy Additions	Tensile Strength, psi	Yield Strength, psi	Elongation, in 2 in., pct	Density, lb/cu in.
Aluminum	2024	Cu, Mg	68,000	47,000	20	0.100
Aluminum	5456 & 5083	Mg	46,000	42,000	16	0.096
Titanium	6Al-4V	Al, V	135,000	125,000	13	0.160
Magnesium	LA142	Li, Al	20,000	17,000	30	0.052
Plastic	Doron	—	—	—	—	0.072
Steel	300 BHN	Mn, Mo	150,000	140,000	16	0.283



SIZE	WEIGHT-GRAINS	"A"	"B"	"C"	"D"	"E"	"F"	"G"	DRAG COEF. h
CAL .22	17.0 ± 0.5	250	.085	100	215	230	200	226	0.00620
CAL 300	44.0 ± 0.5	348	.034	136	296	340	273	309	0.00455
CAL 900	207.0 ± 1.0	582	.088	224	495	560	460	511	0.00274
CAL 20MM	828.0 ± 4.0	912	.091	365	784	910	740	823	0.00184

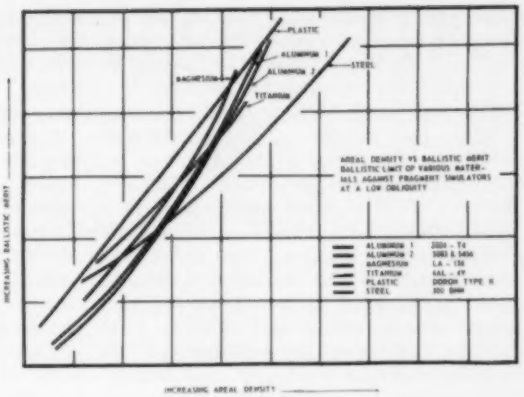
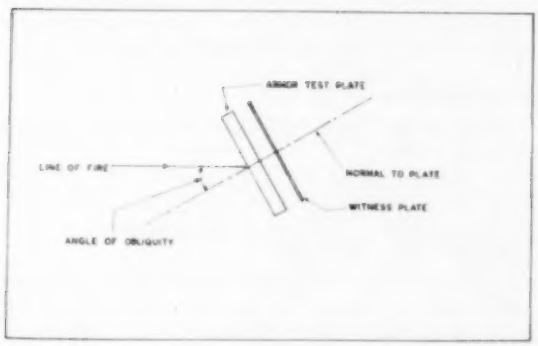
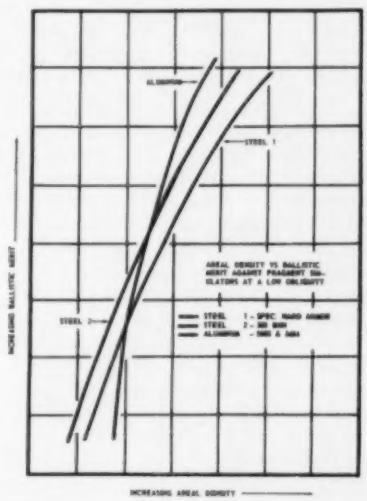


Fig. 3—Upper left, Fragment simulating projectiles. Fig. 4—Below left, Ballistic test arrangement. Fig. 5—Upper right, Areal density vs ballistic merit of various materials at low obliquity. Fig. 6—Below right, Steel vs aluminum at low obliquity.




ALUMINUM
STEEL 1
STEEL 2
AREAL DENSITY VS BALLISTIC MERIT AGAINST FRAGMENT SIMULATORS AT A LOW OBLIQUITY
STEEL 1 - SPEC MIL-A-12560 ARMOR
STEEL 2 - MIL 12560
ALUMINUM - 5083 & 5456
INCREASING BALLISTIC MERIT
INCREASING AREAL DENSITY

fragment evaluation with extensive research programs on alloy development, and weldability, and corrosion characteristics because the necessary information was not available. Table I lists pertinent characteristics of several candidate armor materials.

There is some evidence that the mechanical properties specified for steel to be used for resistance to armor-piercing rounds, are not optimum properties for fragment protection. In the thickness contemplated for use in personnel carriers, the prescribed hardness is approx 340 to 400 BHN. Fragment evaluations have been made on this specification armor and on softer plate—approx 300 BHN—since it was believed that the softer steel plate should offer better resistance to the punching of large fragments.

Of all the commercially-available alloys of aluminum, 2024-T4 was found to offer the best all-round protection in terms of resistance to armor piercing projectiles and fragments. However, this alloy cannot be welded when the areas to be joined are under structural constraint. Therefore, the principal work on aluminum for protective materials has been concerned with the strain-hardened alloys of the aluminum-magnesium family, containing 4.0 to 5.5 pct Mg and 0.3 to 0.75 pct Mn. These alloys are typically work hardened to provide the necessary mechanical properties.

A titanium alloy containing 6 pct Al-4 pct V in the annealed condition was selected for evaluation in concurrence with Watertown Arsenal. Other alloys of titanium have shown no distinct advantages over this one, although several other alloys have approximately equal ballistic merit.

Alloys of magnesium which contain more than 10 pct Li with a bcc matrix, have been found to be markedly superior to hexagonal magnesium alloys with respect to fragment protection. Much work needs to be done to establish the preferred lithium content, the optimum additional alloying ingredients, and the most advantageous thermal and mechanical processing schedules. At the present time, a 14 pct Li-1.5 pct Al alloy represents a desirable compromise of ballistic protection and good weldability. It appears that the best protection is obtained when this alloy is thermally treated to a fully stabilized structure—in this condition the material has excellent ductility at moderate strength levels, as shown in Table I.

Several non-metallic compositions have proved to have outstanding resistance to penetration by fragments and are finding application as body armor. One of these materials is Doron, a rigid aggregate made by bonding laminated glass cloth with a polyester resin. However, at present plastics do not appear useful for combat vehicle armor because in larger thicknesses these materials delaminate extensively under attack by large fragments and by armor piercing rounds.

Since lightly armored vehicles are primarily designed to provide maximum protection against shell fragments, it was necessary to develop ballistic tests to provide the required engineering design data.

The first method employed in the evaluation was to place test samples of known thickness or areal density in a circular arrangement of varying radii and detonating a shell that was placed at the center of the circle. A cursory examination of this test set-up is mindful of a sports arena and thus, the test procedure was aptly named the *Yankee Stadium Test*, shown in Fig. 1. Upon detonation, the test armor is impacted by fragments falling within wide ranges of size, shape, and velocity. It is customary to count and report the percentage of the impacting fragments which perforate the armor. While the data has great significance in finalizing armor design, it must be recognized that a single test requires a large amount of plate material and tedious mathematical analysis to obtain a useful statistic. Fig. 2 illustrates qualitatively the data obtained from a Yankee Stadium comparison of conventional (380 BHN) steel and a weldable aluminum alloy armor.

A second method developed for assessing performance was to detonate a standard high-explosive shell in a sawdust pit, recover the fragments, and screen them into weight classes. The individual shell fragments from a given weight class were then fired at an armor sample to determine the ballistic limit in the conventional fashion. The fragments were individually mounted in plastic cups and fired from standard rifled guns. This test also has its disadvantages. The recovery, screening, and weighing of the fragments is tedious. Even within carefully selected weight classes, the variations in mass and geometry cause a dispersion in the penetration efficiency, making it necessary to fire a large number of fragments to establish a ballistic limit.

Developed as an outgrowth of the first two methods, the third test procedure consists of a series of 10 homologous fragment simulating projectiles weighing between 1.35 and 830 grains. Fig. 3 illustrates the general shape of the simulators with detailed dimensions of the more frequently used ones. The smaller projectiles were fired from a .22 caliber rifle, and the larger ones were made to standard calibers and fired from rifled gun tubes. The simulators are produced from a hardened and tempered steel—R30—which approximates the hardness of the recovered fragments. The typical test set-up is presented in Fig. 4. The test plate is clamped firmly to a rigid support and a 0.020 in. piece of 2024-T4 aluminum is placed 6-in. behind it to serve as a witness plate. The angle of obliquity is defined as the angle between the line of fire and the line normal to the plate surface. Velocity of the projectile can be varied by changing the weight of the powder charge. Firings are continued until a statistical estimate is obtained of the velocity at which there is a 50 pct chance that either the projectile or a fragment from the plate is discharged with sufficient momentum to perforate the witness plate. Fragment simulating projectiles are usually fired normal to the plate surface (0° obliquity), in order to present a consistent attacking front. The results of fragment simulator evaluations of various materials are shown in Fig. 5.

Evaluation of resistance to small arms armor piercing projectiles was performed in much the same manner as for fragment simulating projectiles, except that the angle of obliquity was varied from 0° to 60°. As illustrated in Fig. 6, weldable aluminum alloy plate offers greater protection toward armor piercing projectiles at 0° than does steel armor. However, at intermediate obliquities on the order of 30° to 45°, the order of protection is reversed. At very high obliquities the order is again reversed, and aluminum is superior. Magnesium-lithium alloys have not been incorporated in this comparison because their evaluation is not as yet complete. However, current indications are that these alloys are approximately equal or possibly slightly superior to aluminum alloy 2024-T4.

Availability and cost

Both steel and aluminum industrial production is adequate to provide the armor plate required in any vehicular construction program. Aluminum armor would cost slightly more than steel but the overall cost should not be more than 5 pct. Titanium is potentially available in virtually unlimited quantities, but at present, only limited quantities of plate are produced and costs have not been stabilized. A considerable cost differential would be involved in the use of titanium. Magnesium-lithium alloys are not yet ready for commercial exploitation. Since extensive quantities of lithium are employed, the cost of these alloys would be quite high.

Conclusions

From the data obtained the following conclusions may be stated:

1) Aluminum alloys are superior to steel and titanium in resisting high-velocity fragment; however, the order is reversed when fragments at lower velocities are concerned;

2) Titanium is superior to steel at all fragment velocities;

3) Magnesium shows promise as an armor material;

4) Plastic armor materials are useful, particularly in stopping small fragments traveling at relatively low velocities; and

5) For protection against armor-piercing projectiles, the effectiveness of steel and aluminum materials depends upon the angle of obliquity.

Research tasks

Although work on other candidate materials will be continued as a long range program, at the moment, economic factors have limited the selection of armor for air-droppable vehicles to steel and weldable aluminum alloys. Since it is anticipated that only limited improvement of the current strain-hardened alloys can be affected by further cold work or by alloy modification, attention is being directed toward the development of heat-treated alloys having adequate weldability, and the parallel development of welding techniques to facilitate fabrication of hulls constructed from these new alloys.

Another program of immediate interest is the evaluation of composite structures, utilizing two or more materials in combination. It has been suggested that an aggregate structure of a hard plate and a softer material might have better properties than the materials presently used. Current investigations are now underway to evaluate various combinations of steel, titanium, aluminum, and magnesium alloys.

STEEL FROM COPPER SLAGS

A significant step toward the completion of plans for one of the largest steel mills in the Pacific Northwest was made with the initial prototype run at Strategic Materials Corp's pilot-plant at Niagara Falls, Ontario, Canada. The operation utilized a modification of the Strategic-Udy process to produce steel from waste copper slags.

by E. J. Fitzgerald

Utilizing a modification of the Strategic-Udy process, already applicable for low-grade manganese and iron ores, it is possible to produce steels from heretofore waste copper slags. This was demonstrated by a test run at the Niagara Falls, Ontario, pilot-plant of Strategic Materials Corp., which produced approx 200 tons of steel from 700 tons of Anaconda copper slag. Availability of copper slags should make the process significant, for besides the 40-million ton slag pile at Anaconda, Mont., and 30-million tons at Clarkdale, Ariz., there are two other major deposits in the US alone.

The pilot-plant is to be used as a prototype for a $30-million plant on which construction is expected to begin in the very near future. This plant, which will be located adjacent to the Anaconda smelter, is expected to produce 1000 tons of steel per day from hot slag, with fluctuations in demand to be met by the utilization of cold slag.

Webb & Knapp-Strategic Corp.—owned jointly by Webb & Knapp, Inc.* and Strategic Materials Corp.—has already contracted the Bonneville Power Administration to supply the necessary power starting July 1, 1963; the firm has also agreed with Anaconda to purchase the slag at 25 cents per ton. In addition, Webb & Knapp owns the 30-million ton slag dump at Clarkdale, and plans a similar operation there as described in the December 1959 issue of the JOURNAL OF METALS.

Slightly less than 3 tons of slag are required to produce a ton of steel. The Anaconda slag contains 33-37 pct Fe, 0.7 pct Cu, 2 pct Zn, with the remainder silica and traces of other metals, while the Clarkdale slag contains about 33 pct Fe, 0.5 pct Cu, and 2 pct Zn.

Considerable amounts of power are required for the operation; hence, the Aanconda site appears superior to Clarkdale from an economic point of view. Preliminary geological surveys have ascertained that adequate ground water and fluxing limestone are available near the Anaconda location. This is important because the process requires more than 2 tons of lime per ton of steel produced.

A feature of the process is that it is amenable to the utilization of a wide variety of coals as a reducing agent in the first electric furnace. Although the pilot test was run with a medium quality coal, lignites are expected to be used in subsequent tests.

Substantial amounts of iron pyrites are required for the process. Forecasts indicate that the Montana operation will require 50,000 tons of this material per year.

The 25-tpd pilot-plant flowsheet consists of a 20-ft gas fired rotary kiln and three 1000 kva electric furnaces. Processing the slag differs from Strategic-Udy's low-grade ore operation in that the kiln is used only to preheat and calcine the limestone rather than for pre-reducing the charged material. The kiln utilizes the CO-rich gas from the electric furnace to supply the necessary heat.

Preheated lime is charged with copper slag, pyrites, and coal into the electric matting furnace. During the operation, zinc volatilizes from the melt and is collected as zinc oxide. A majority of the copper and some iron form a copper-iron matte containing 16-17 pct Fe and 4-5 pct Cu at the bottom of the furnace. In addition, a copper-free iron-silica slag is formed. Copper-iron matte is tapped periodically through the lower tap hole. This matte can be either sold directly or given further treatment. If it is up-graded, the recovered iron can be fed directly into the smelting furnace.

In the second furnace, the smelting furnace, the iron-silica slag, containing 0.30-0.35 pct Cu, is refined to a *semi-steel* by the addition of coke and lime. Although this metal could be considered a pig iron, its 1.00-1.25 pct C would indicate that semi-steel is more descriptive. After refining, the semi-steel contains about 0.12 pct P, 0.3 pct S, and a nominal amount of silicon. The *slag-slag*, which forms during the smelting operation, is skimmed off, and then the metal is transferred to the 3-ton, 1000-kva steelmaking furnace.

The following table illustrates the amount of raw materials necessary to produce 1 ton of steel and the various by-products produced:

Raw Materials, lb	Products, lb
Slag, 5500	Steel, 2000
Limestone, 4700	Slag-Slag, 5000
Coal, 600	Zinc oxide, 150
Iron pyrite, 440	Sulfur, 150
	Copper, 25

While all economic considerations have not yet been completely resolved, it appears that the process could be an important development in the economic production of steel. A Strategic process plant, using waste slag or low grade ore could, it is claimed, be built for under $50-million and be economically feasible for a market area where economics and raw material conditions do not justify a major complex.

* It was announced later that Webb & Knapp, Inc. has transferred its interests in the project to its subsidiary, Gulf States Land & Industries, Inc., in a move that will substantially re-orient and expand the activities of Gulf States Land & Industries.

LABORATORY CASTING HIGH-TEMPERATURE METALS

A furnace, developed as a laboratory tool for studying the application of skull-casting techniques to high-temperature metals, has been used successfully to produce small castings of various reactive and refractory metals. Because of its small size, the apparatus has been useful in studying the casting characteristics of costly and hard-to-melt metals.

by P. G. Clites and E. D. Calvert

Late in 1958, eight to ten spectrographic standards of hafnium, containing varying amounts of impurities, were needed at the USBM's Albany Metallurgy Research Center. Previously prepared standards from arc-melted ingots lacked the homogeneity desired, and it was impossible to prepare the samples in a graphite resistor furnace because of the high temperatures involved. Consequently, it was decided to construct a small, over-the-lip casting mechanism and consumably arc-melt and cast the required standards. The general configuration of the ladle was based on large-scale equipment described earlier.[1]

P. G. CLITES and E. D. CALVERT are with the US Bureau of Mines' Albany Metallurgy Research Center, Albany, Ore.

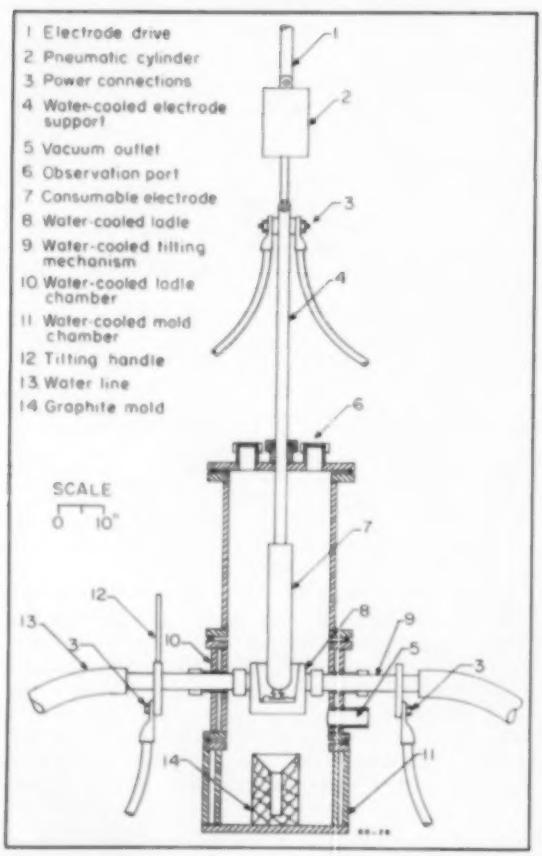


Fig. 1—Laboratory-scale casting furnace.

This laboratory-scale equipment has since been used extensively for studying variables associated with the casting of such high temperature metals as columbium, molybdenum, tantalum, and tungsten. Because of its small size, this equipment has been particularly valuable in studying the casting characteristics of materials that are expensive, in short-supply, or which melt with such difficulty as frequently to cause damage to the furnace. Repair of this damage is much less expensive and can be accomplished with much less delay on this furnace than on large-scale equipment. Many of the casting characteristics of metals and alloys can be determined on equipment of this size, although additional work is necessary to determine the extent to which the information obtained can be extrapolated to larger furnaces of the same type.

Equipment

An existing, 4-in. diam ingot furnace was modified by replacing the ingot crucible and its water jacket with a water-cooled ladle, ladle chamber, and mold chamber. In addition, an air cylinder was added to the electrode drive to provide rapid withdrawal of the electrode prior to tilting the ladle. By modifying an ingot furnace it was possible to utilize the existing vacuum system and electrical controls for the casting operation. The furnace, with these modifications, is illustrated in Fig. 1, while Fig. 2 shows details of the ladle, ladle chamber, and mold chamber.

The ladle is approximately 4 in. deep and tapers from 3-in. diam at the bottom to 3.5 in. at the top. This provides a volume of approx 20-cu in. of molten metal for castings. The ladle liner was formed by spinning a length of standard 3-in. copper pipe to form the lip. After the spinning operation, a steel mandrel was pressed into the liner to form the tapered sides which facilitate removal of the skull following each heat. The liner bottom was turned from ¼-in. copper plate and brazed in position, and the liner was brazed to the outer wall of the ladle. This liner was frequently damaged when experimental melting of high-temperature metals was attempted, but removal of the liner was easily accomplished by machining the brazed joint between the lip of the liner and the outer wall of the ladle.

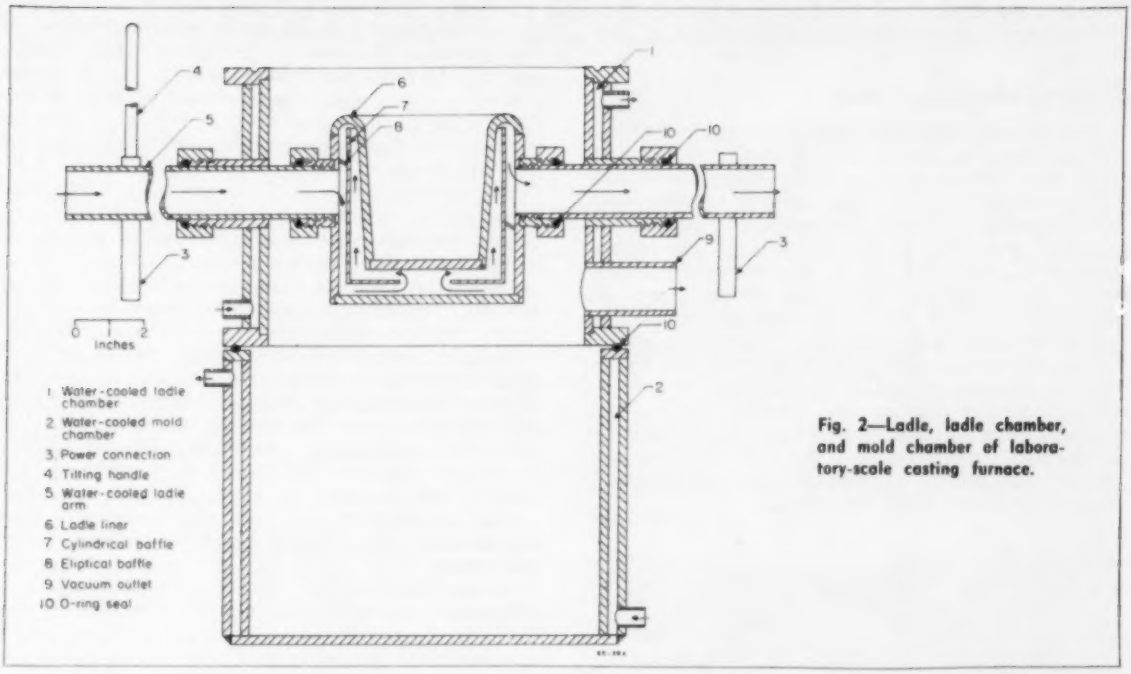


Fig. 2—Ladle, ladle chamber, and mold chamber of laboratory-scale casting furnace.

It is important that proper spacing between the lip of the liner and the top of the cylindrical baffle be maintained to assure adequate coolant flow at this critical portion of the ladle. Cooling water enters one arm of the ladle, is directed downward along its outer wall, and impinges upward against the bottom of the ladle liner. It then flows upward along the inner wall of the liner and out the other arm. Water flow is varied from 10- to 15-gpm for metals with low melting points to as much as 60-gpm for tungsten. The arms also provide electrical contact to the ladle.

Electrical power for the furnace is obtained from the laboratory power supply which consists of 18 selenium rectifiers connected in parallel. Open circuit voltage for this network is 70-v. Arc current available to the furnace is limited to 8000-amp by the shunt used for metering; however, ample power is available for melting all metals, including tungsten. In operation, the ladle is positive and the electrode is negative, and it has been found desirable to provide electrical symmetry by making connections to both arms of the ladle rather than to just one. This minimizes undesirable magnetic effects on the positioning of the arc during operation.

Provisions were made to operate either in a vacuum or in an atmosphere of inert gas, usually helium. Pressure in the furnace is measured in the vacuum line approx 4 in. from the furnace body and varies from 35 μ before striking the arc to nearly 1 mm Hg during the melt, depending upon the material melted. A vacuum pump with a free-air capacity of 110 cfm is more than ample for the system. Occasionally, when working with metals of high vapor pressure, the furnace is backfilled with approx ½ atm of helium to reduce vaporization of the metal.

Furnace operation

Selection and fabrication of the electrode initiates the melting operation. Castings are made using electrodes prepared from sponge, machine turnings, sintered powder, sintered and forged powder, and from previously-melted material. The most satisfactory electrodes are 1- to 2-in. diam round rods of previously-melted material. The electrodes are attached to the water-cooled electrode support by means of a threaded joint which is machined on the electrode, or if the electrode can not be machined, a stub of suitable material is welded to the electrode. The electrode has to be strong enough to support itself without breaking during the melt and have sufficient electrical conductivity to carry the required current. A 2-in. diam electrode, 20 in. long, provides ample metal for a series of three or four runs and can easily be accommodated.

For all heats it is necessary to provide some type of starting pad in the bottom of the ladle on which to initiate the arc. If the skull from a previous melt is available this is placed in the ladle, and a small amount of chopped turnings is placed in the bottom of the skull to prevent sticking. When no skull is available, additional turnings are placed in the bottom of the ladle to serve as the starting pad. The amount used varies with the metal being melted, but should be sufficient to cover the bottom of the ladle to a depth of at least ½-in.

After the electrode and base have been loaded into the furnace and the mold has been placed in position, the furnace is closed and evacuated. When the proper furnace pressure has been attained, the electrode is lowered until an arc is initiated between the electrode and the starting pad. Starting electrical power requirements have to be high enough to melt the starting pad and yet low enough to prevent rupture of the ladle. A typical starting arc current for zirconium is approx 1500 amp.

As soon as the base has been consolidated into a molten pool, the power is raised sufficiently to cause the electrode to be consumed. The electrode is fed downward as it is consumed so that a uniform arc potential is maintained. When the required amount of metal has been melted the arc is terminated, the ladle tipped, and the contents poured into the mold.

The pouring cycle from the time the arc is extinguished until the metal is poured, generally is 2 sec or less.

Casting characteristics

This furnace has been in operation approximately one and one-half years, and in that time attempts have been made to cast a variety of metals, including titanium, zirconium, hafnium, columbium, molybdenum, tantalum, tungsten, chromium, copper, and iron. The metals, titanium and zirconium, have been used extensively on large-scale equipment at the Albany Station for several years and presented no new problems with the small-scale equipment. Hafnium likewise presented no particular problem, although lack of material has limited the work done with this metal. But columbium, molybdenum, tantalum, and tungsten deserve special attention because considerable work has been performed with these, and the increased emphasis on the application of high-temperature materials makes them especially interesting.

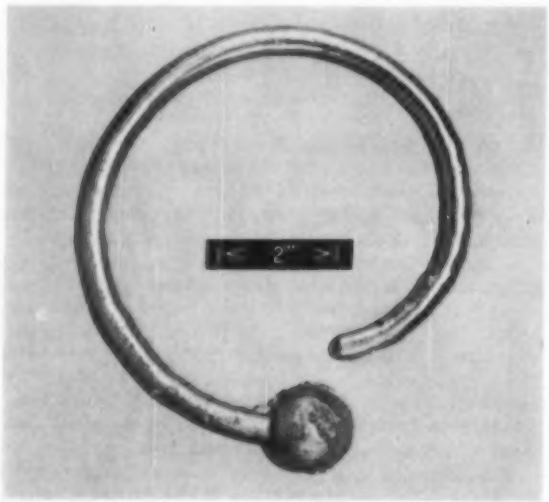


Fig. 3—Fluidity spiral of columbium.

Fig. 4—Two unalloyed tungsten castings.

Columbium lends itself particularly well to the process and excellent results have been obtained in this furnace. The castings produced were ductile, and the surfaces were well defined. Fig. 3 shows a fluidity spiral cast in a machined graphite mold. The runner of this spiral was 18 in. long—only 3 in. shorter than the best titanium spiral produced with this equipment.

Molybdenum can readily be arc melted, but it is necessary to maintain higher arc potentials than when melting other metals. Fluidity spirals of molybdenum have been produced with runners 11 in. long, but the castings are extremely brittle. However, centrifugal castings produced in a larger casting furnace were reported to be more ductile.[2]

Tantalum has a sufficiently high melting point to cause difficulty in the casting process. But the results of the heats conducted thus far have shown that tantalum castings can be produced, and the resultant castings do have desirable properties. Tantalum castings, like those of columbium, are ductile and the surfaces of the castings are generally fair. Recently, a series of 12 successful tantalum runs was conducted without failure of the ladle liner.

Prior attempts to cast unalloyed tungsten in this laboratory had frequently ended in failure of the ladle liner. In only one instance was any metal poured from the ladle, and this could hardly be classified as a casting. A series of tungsten heats have been completed, and the heaviest casting produced thus far weighed 10-lb. Fig. 4 shows two unalloyed tungsten castings. Careful examination of the surfaces will disclose evidence of surface reaction between the metal and the graphite mold. Analysis of turnings from the castings has shown that carbon contamination due to mold reaction does not extend beyond a depth of 0.025 in.

In addition to data related to the casting of these individual metals, this furnace has been useful in studying the inter-relationship between the various operating variables associated with arc melting. Of particular interest has been the effect of increased coolant flow to the ladle and the corresponding increase in arc current required to maintain a deep molten pool when melting high-temperature metals. Experience with zirconium and molybdenum heats indicates that it is possible to maintain high casting efficiencies (ratio of casting weight to total metal involved in melt) when operating with increased coolant flow rates by increasing the power input. This information proved valuable during the early phases of tungsten melting and casting.

Conclusion

Because of the simplicity and versatility of this furnace, it has been a valuable laboratory tool. Other groups probably could profit by the installation of similar equipment, particularly when the equipment can be a simple modification of standard ingot furnaces. Laboratories that are already operating consumable electrode arc furnaces or plan to install such furnaces could incorporate this type of casting equipment to produce cast metallurgical specimens.

References

[1] R. A. Beall, F. W. Wood, J. O. Borg, and H. L. Gilbert: Production of Titanium Castings, Bureau of Mines Report of Investigations no. 5263, August 1956.

[2] E. D. Calvert, S. L. Ausmus, S. L. O'Hare, and A. H. Roberson: Molybdenum Casting Development, Bureau of Mines Report of Investigations no. 5355, May 1959.

BERYLLIUM DEVELOPMENTS

1. French Production

This side of the Iron Curtain and outside of US borders, there is only one major producer of beryllium—Pechiney in France. So, during a recent visit to the city by the Seine we took advantage of French hospitality and paid a visit to Monsieur Roy, Pechiney's engineer in charge of new product research.

We learned that Pechiney has been in the beryllium business since 1951, supplying metal in the form of ingots, flakes, powder, sintered or forged shapes, plates, bars, tubes, and forged pieces. The firm is the only producer to base its operations on the electrolysis of beryllium chloride. Beryl ore, largely from Madagascar, is refined to BeO at the firm's chemical plant at Salindres in southern France, and transformed to metallic beryllium at the Calypso plant high in the French Alps, near Pechiney's aluminum reduction works. Calypso is an old electrolytic reduction works which was modernized in 1958 and put exclusively into beryllium service.

First step in the production of beryllium at Calypso is the mixing and briquetting of powdered beryllium oxide and carbon. The resulting briquettes are charged into the classical type of chloridizing furnace. Temperatures are maintained at 900°C while chlorine gas is injected into the furnace and the more easily sublimed metallic chlorides, including beryllium, are allowed to pass from the unit.

After condensation, the resulting crude chloride is passed through a series of purification steps which are vital to the production of high-purity beryllium. By means of precise control over sublimation and condensation conditions, low-temperature chlorides are first sublimed by heating to temperatures below 900°C. At a later step, higher sublimation-point chlorides are left as a residue, while beryllium chloride is sublimed. The resulting purified chloride contains no silicon, less than 0.1 pct Al + Fe, and only a small quantity of oxygen.

Fused-salt electrolysis of the eutectic mixture of purified beryllium chloride and sodium chloride (about 45 pct NaCl) is the next step. The operation takes place at temperatures between 350° and 400°C in nickel cells operating at 1000 amp. The pot itself serves as the cathode, while a graphite anode is employed. Periodically, beryllium metal, together with a certain amount of the electrolyte, is gathered from the side of the cell and transferred to another area where water and acid are employed to wash the beryllium free of such impurities as nickel.

Washed beryllium metal has the following analysis: 300 ppm C, 300 ppm Na, 200 ppm Ca, 50 ppm Mg, 300 pm Si, 300 ppm Fe, 300 ppm Al, 200 ppm Ni, 1100 ppm halogens (except F) expressed as Cl, and 4000 ppm insolubles in bromine-alcohol (assumed to be oxides of beryllium). The metal is further refined by vacuum melting in an induction furnace, and the resulting ingot shows a considerably lower halogen content. Beryllium ingots may be made into chips which are ground in a ball mill into beryllium powder.

Recently, Pechiney has begun the trial production of some 1 kg per day of refined beryllium through the utilization of a second fused-salt electrolysis in a cell not unlike that used experimentally by the US Bureau of Mines and reported in the October 1960 issue of JOURNAL OF METALS. Pechiney's refined beryllium is made according to the following chemical specifications: 100 ppm C, 20 ppm Si, 20 ppm Fe, 10 ppm Ni, 50 ppm Na, 5 ppm Cu, 20 ppm Mn, 20 ppm Zn, 1 ppm Ti, 500 ppm halogens, and 300 ppm insolubles. According to spectrographic analysis this metal contains 5 ppm Mg, 10 ppm Ca, 20 ppm Al, and 0.5 ppm B. Under study by Pechiney is the production of ingots and powder from this refined metal.

As an added crown to its achievements Pechiney is experimenting with a new electrolysis technique designed to produce metal containing less than 5 ppm total impurities. Thus, the quest for perfection is in sight!

2. US Self-Sufficiency

Bruce W. Odlum, President of Beryllium Resources Inc., expects the US to be self sufficient in beryllium concentrates within a few years, thanks to the continuing exploration of deposits and the development of beneficiation techniques.

Previously based only on the limited deposits of beryl, the industry is now turning its eyes toward more plentiful deposits of other beryllium-containing minerals. Draw-back to the utilization of these low-grade ores has been a means of concentration.

In order to accomplish this task, Mr. Odlum's firm was established, taking as its technological starting point a flotation process developed by Edward Van Dornick for beryl. After several years of pilot-plant work, satisfactory beryllium concentrates have been produced from phenacite, bertrandite, helvite, and other minerals.

So successful has been the work, that Beryllium Resources is now constructing a 250-tpd mill to process bertrandite-like ores from the Topaz Mountain region of Utah. This mill is expected to be in operation before the end of 1961, processing 1 pct BeO-containing ores to a 7-pct BeO concentrate, reportedly satisfactory for beryllium extraction. With a better-than 90 pct recovery, output of this mill—some 2 pct of contained BeO per day—should be adequate to supply not only Brush Beryllium Co. (a stockholder), but some requirements of The Beryllium Corp. as well.

Continuing its exploration work, Beryllium Resources has mining claims in a number of states including Alaska. It is also putting its technical know-how to work in attempts to recover beryl from mine waste dumps, probably in such places as Mozambique. There hand cobbling has recovered only about half of the beryl contained in the ore.

The application of flotation techniques to non-beryl beryllium minerals is likely to mean US self-sufficiency in raw materials for beryllium production. And this, together with the application of flotation to beryl mining operations in various parts of the world, may indeed spell the end to the raw materials bottle-neck of the beryllium industry.

F. Weston Starratt

COLD-CRUCIBLE INDUCTION MELTING OF REACTIVE METALS

Most reactive metals are currently produced by the consumable-electrode process. Research and development of a cold crucible for induction melting has demonstrated that the process is technically feasible. This paper discusses the objectives, investigations, and the results of the initial research program carried-out at Battelle Memorial Institute.

by G. H. Schippereit, A. F. Leatherman, and D. Evers

At the present time, producers of reactive metals such as titanium, use the consumable-electrode process to arc melt ingots in a water-cooled, metal crucible. This process, although rather widely used not only for reactive metals but also for special steels, has some disadvantages. Induction melting, in which a water-cooled metal crucible would hold the charge, offers the possibility of eliminating some of these disadvantages. However, before it could be predicted whether such a furnace would provide real promise and before a likely design could be visualized, it was necessary to determine if an electrically-efficient, water-cooled metal crucible could be developed that would not impose impractical power requirements, and would be compatible with reactive metals. This called for a design that would allow sufficient conservation of heat without danger of wetting the crucible, and would also provide structural soundness and simplicity of design for economical fabrication. It was believed that it might be possible to achieve this result, if melting were conducted in a water-cooled, metal crucible consisting of electrically insulated segments.

As a result of a research program conducted at Battelle Memorial Institute under the sponsorship of Mallory-Sharon Metals Corp. (now Reactive Metals Inc.), a successful design of a cold-crucible induction furnace for melting reactive metals was developed and demonstrated on a laboratory scale. Further research on this melting technique, featuring a water-cooled copper crucible 14 in. in diam is presently being conducted by Reactive Metals and Battelle for the Air Materiel Command, US Air Force. In this paper, the objectives, investigations, and results of the initial research program are presented.

Induced current reduction

Two effects were expected during the induction melting of titanium in an electrically-conductive crucible of copper with thick walls. First, it was expected that the crucible itself would be heated by induced currents. Some of this heat would be conducted to the cooling system surrounding the metal crucible. However, if the heating were intense, the crucible could become too hot and the charge would wet the crucible, either contaminating the charge or damaging the crucible. Second, it was expected that the currents induced in the wall of the metal crucible would be sufficiently high so as to attenuate a large portion of the applied magnetic flux and thus seriously reduce the amount of power available to heat the charge. Under operating conditions, this attenuation or shielding of the field could be essentially 100 pct, and the charge would not be heated. Therefore, if a metal crucible were to be used for induction melting, it was necessary to find a method of reducing the currents induced in the crucible wall to an insignificant level.

Two possible means were considered for reducing the current flow in the crucible wall: 1) to make the crucible wall *electrically thin* and use low-frequency induction heating, or 2) to interrupt the current paths altogether so that circumferential currents could not flow. The idea of making the wall electrically thin was based on the same type of reasoning which is applied to the design of transformer laminations. In effect, if the object in the induction field is physically smaller in thickness than a particular reference dimension, sometimes called the depth of current penetration, the current induced in it will be relatively small. The reference dimension for a non-magnetic cylindrical work piece is determined by the resistivity of the work piece and the frequency of the applied magnetic field. Under these conditions, it is defined by the expression

$$S = 1.98\sqrt{r/f},$$

where S = reference dimension in in.,
r = resistivity of the load material in μ-ohm cm, and
f = frequency of the applied field in cps.

Since it was necessary to experiment with a charge of a relatively small diameter, a frequency of 2000-cps was used to obtain good coupling. The proposition of making a copper crucible that would be electrically thin at 2000-cps appeared to impose mechanical limitations. Therefore, some experiments were conducted with stainless-steel crucibles, which offered a relatively high resistivity and, therefore, do not need to be as thin as copper. However, sticking and alloying occurred in melting experiments with stainless-steel crucibles. Hence, the majority

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of effort was restricted to consideration of copper crucibles and the use of the second method—interrupting the current path—to reduce induced currents in the crucible wall. Assuming that poor electrical contact exists between the charge and the crucible wall, the current paths can be interrupted by making one or more longitudinal slits through the crucible wall.

Small crucible models

To devise a satisfactory segmented design, it was necessary to determine the degree of attenuation of the magnetic field by the crucible wall. The design parameters studied were the number of slits in the crucible and the crucible wall thickness. The actual quantity measured was the density of the magnetic flux present inside various crucible models. The fields were produced by simple, single-layer work coils of conventional design. Frequencies ranging from 60 to 5000 cps were used. Copper crucible models were studied which had an outside diam of 3½ in. and were 4⅞-in. high with wall thicknesses of ⅛ and ¼ in. Zero, one, two, or four slits were employed.

The intensity of the magnetic field at different locations inside each crucible was determined with a probe coil whose voltage output was proportional to the frequency and the average density of the magnetic flux within the probe coil. Since all determinations were made in air, with magnetic permeability of approximately unity, flux density and magnetic-field intensity were approximately equal. Consequently, field intensity or magnetizing force could be used interchangeably with flux density.

It should be noted that these measurements indicate attenuation of the magnetic field by the crucible rather than attenuation of actual power. Field strength at any point can be used to determine the available power at that point. For purposes of reference, the magnetic field strength within the work coil without a crucible was assumed to represent zero attenuation. The results of the attenuation measurements are presented in Table I.

The values given for attenuation of magnetic field can be used to indicate the percentage of the total power capacity of the coil that is nullified or shielded by the copper and, therefore, is not available for heating a charge. For example, the unslotted metal crucible with a wall thickness of ⅛-in. causes a field attenuation of 90 pct at 500 cps. Since heating of the charge is proportional to the square of the field strength, only 1 pct of the normal power capacity of the coil would be available in this copper crucible. With no slits in the crucible, the attenuation of the applied magnetic field is increased when either the frequency or the wall thickness is increased. With an unslit crucible, the attenuation becomes very nearly 100 pct at the higher frequencies. The reason for this again follows from the theory of induction heating and transformer design. The advantage realized in slitting the crucibles is clearly indicated.

Analysis of the results of these studies shows that, when a crucible is divided into several electrically insulated segments, heavier wall thickness and higher frequency can be used without seriously increasing the attenuation of the field. This means that sturdy construction of the crucible should be possible and that high power input to the charge can be obtained with induction melting equipment operating in the range of frequencies investigated.

Table I. Effect of Frequency and Crucible Design on the Attenuation of the Applied Magnetic Field within Small Copper Crucibles.[a]

No. of Slits	Wall Thickness, In.	Attenuation, pct					
		Frequency, cps					
		60	200	500	1000	2000	5000
0	0.125	30	78	90	95	98	99
1	0.125	4	14	17	15	17	17
2	0.125	2	15	15	15	18	16
4	0.125	3	10	15	13	13	10
0	0.250	57	90	95	98	99	99
1	0.250	6	17	18	12	19	18
2	0.250	7	17	17	15	16	15
4	0.250	4	13	16	13	13	10

[a] Measured at the central axis of the work coil.

Large crucible models

Attenuation measurements on small crucible models showed that even one slit would reduce the attenuation to a satisfactory level for low frequencies. In large crucibles, of the size contemplated for commercial use, it was expected that four slits or less would also reduce the attenuation, but perhaps not to the same degree as for small crucibles. This would be particularly true, if the configuration of the magnetic field with work coils of larger diameter were less favorable. By less favorable, it is meant that the direction of the magnetic field throughout the volume enclosed by the coil would be less parallel to the central axis of the coil. If this were the case, more current would be induced in each section of a segmented crucible, resulting in greater attenuation of the field.

To find the extent to which slits are effective in large crucibles, a limited investigation was conducted to determine the attenuation by a copper crucible approximately the size contemplated for commercial practice. The crucible used was 21-in. O.D., 25-in. high, with a ½-in. wall thickness. The amounts of attenuation measured for this copper crucible in a magnetic field having an intensity of 15 amp turns per in. are presented in Table II.

Table II. Effect of Frequency and Crucible Design on the Attenuation of an Applied Magnetic Field[a] within Large Copper Crucibles.[b]

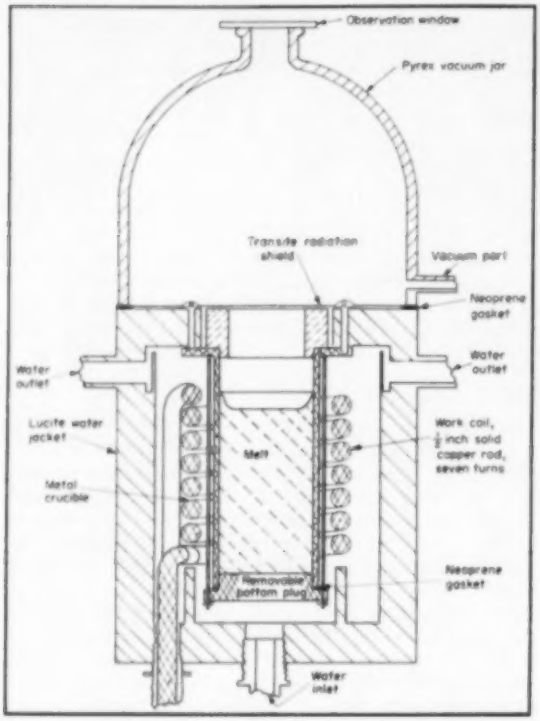
No. of Slits	Attenuation, pct					
	Frequency, cps					
	60	200	500	1000	2000	5000
0	97	99	99	99	99	99
1	12	14	10	12	11	12
2	10	12	9	12	11	12
4	8	9	11	13	10	11

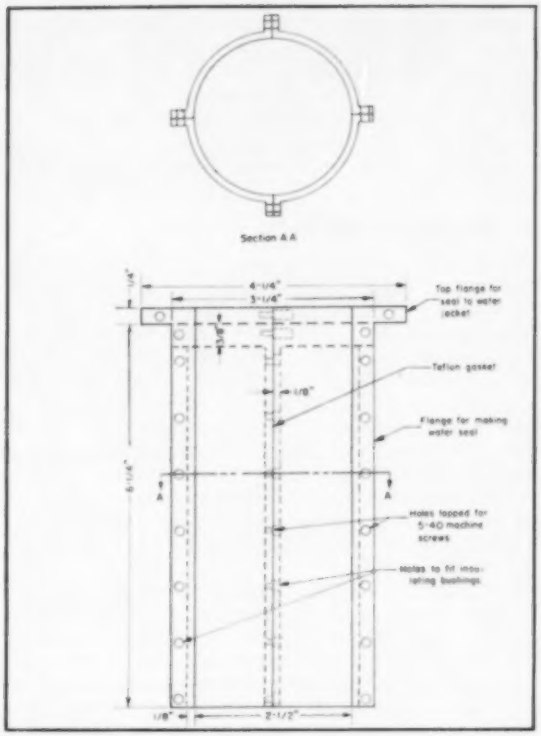
[a] 15 amp-turns per in.
[b] Measured at the central axis of the work coil.

Table III. Effect of Number of Slits on Power Dissipated in the Wall of a Large Copper Crucible[a]

No. of Slits[b]	Power Dissipated in Crucible Wall, kw	Theoretical Power Generated in a Titanium Charge, kw
0	0.576	0.016
1	0.238	13.4
2	0.294	14.2
4	0.384	15.6

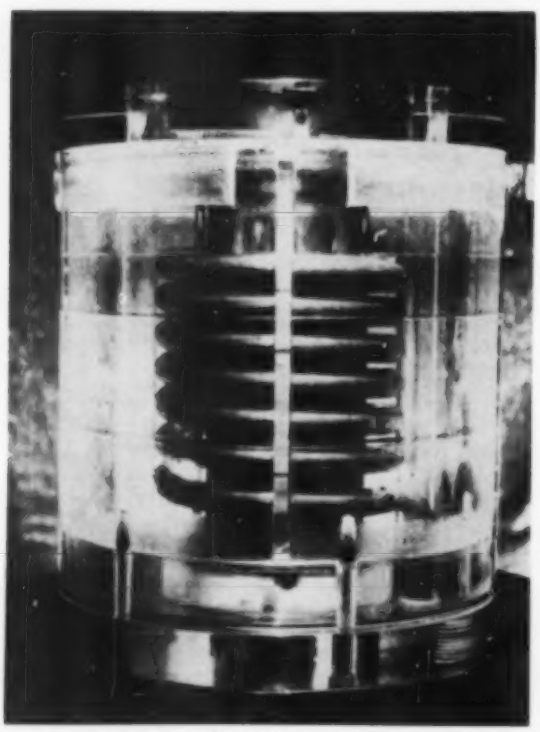
[a] Applied field intensity 430 amp-turns per in.
[b] Crucible was 21-in. O.D., 25-in. high, and had a wall thickness of ½-in.




Section A-A
Top flange for seal to water jacket
Teflon gasket
Flange for making water seal
Holes tapped for 5-40 machine screws
Holes to fit insulating bushings

COLD-CRUCIBLE INDUCTION FURNACE

Fig 1—Above, Schematic drawing of the experimental melting apparatus. Fig. 2—Below, Side view of melting apparatus. Fig. 3—Above right, Schematic drawing of the 4-section crucible.



Large, slotted, copper crucibles exhibited very nearly the same attenuation as the smaller crucibles. Hence, it was demonstrated that, if the circumferential current paths around the crucible are interrupted by slits, there need be no restrictions on the crucible sizes of interest in commercial furnaces, insofar as magnetic-field attenuation is concerned.

Further research indicated that the degree of attenuation is essentially independent of the strength of the magnetic field. Thus, extrapolation of attenuation values to high field intensities, such as would be required in commercial melting, can be made with confidence.

In large crucibles as with small ones, it was found that when several slits were used, electrically efficient thick-walled crucibles could be constructed of copper. Again, four slits appeared to be a good choice.

Power dissipation

The amount of power dissipated in the crucible wall itself is important in determining the electrical efficiency. It is also an important factor in determining the temperature of the inside surface of the crucible. If power dissipation in the crucible wall is large, a larger quantity of cooling water would be required to maintain the inner wall at a temperature low enough to prevent wetting of the copper crucible by the molten charge. To obtain some idea of the magnitude of this factor, a limited study was made of the power dissipated in the crucible wall.

Power dissipated in the walls of copper crucible models was determined experimentally. Thermocouples were used to measure the increase in temperature of the crucible wall, while the crucible was subjected to a known applied field. Power input to the crucible wall in each case was then calculated from these data.

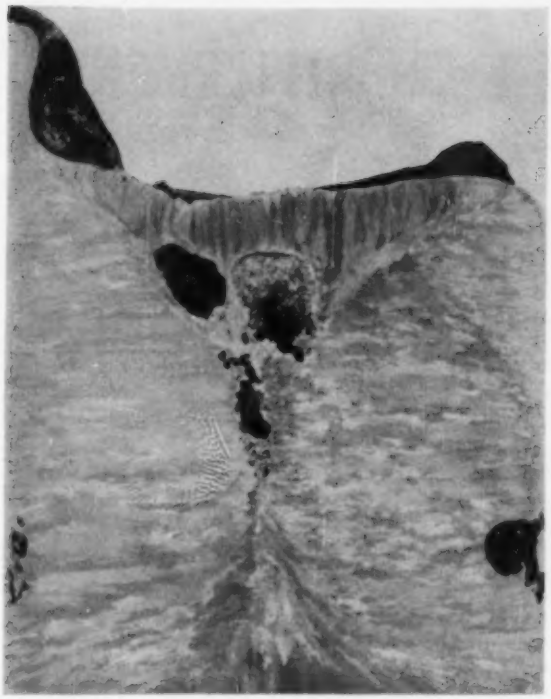


Fig. 4—Cross section of part of an ingot melted in furnace. IX. Increased 13.5 pct for reproduction.

The experimental values for power input to the wall of a large copper crucible with zero to four slits are presented in Table III. For an applied field intensity of 430-amp-turns per in., the power generated in the wall of the copper crucible with four slits is only two-thirds as great as that generated in the wall of the copper crucible with no slits for the same applied field intensity. Again, these data illustrate the importance of interrupting the current paths to improve the electrical efficiency of the melting furnace. Also shown in Table III are calculated theoretical power inputs to a titanium charge with the same applied field. The amounts of power dissipated in the crucible wall, compared with power input to the charge, were not considered sufficient to interfere with the proper operation of the furnace.

Melting experiments

To verify the conclusions drawn from the study of the electrical design of the crucible, induction melts of titanium were made in a laboratory-size crucible. The melting apparatus consisted essentially of a segmented metal crucible mounted in a work coil inside a Lucite water jacket. A cross-sectional view of the arrangement is shown in Fig. 1. Fig. 2 shows a side view of the experimental induction furnace.

The power source for these melting experiments was a 2000-cycle, 100-kw motor-generator, rated at 900-v and 150-amp output. The output of the generator was matched to a simple seven-turn helical work coil by means of an eight to one water-cooled transformer. With this transformer, and capacitors to correct power factor, a measured current of approx 3500 amp was delivered to the work coil at full power.

A copper crucible, constructed for evaluation, was made in four sections and had an internal diam of 2½ in., a wall thickness of ⅛ in., and was 6½ in. in length. An electrically insulated plug was used for the bottom. A drawing of a crucible used in the experiments is shown in Fig. 3.

The objectives of the melting experiments were to:

1) Demonstrate that titanium billets can be melted by induction in a water-cooled metal crucible; and
2) Measure the power, water-cooling requirements, and electrical operating characteristics for use, as a first approximation, in estimating the commercial feasibility of the process.

Solid, commercially-pure titanium charges about 2 in. in diam and 5 in. long were used. The billets were successfully induction melted in the copper crucible without any indication of wetting or short-circuiting between the segments of the crucible. In a typical case, complete melting was obtained within 2 min with a total power input to the transformer and coil of 80-kw. Vigorous stirring action, typical of induction melting, occurred during the time the charge was molten and the power was on. A cross section of part of an ingot melted in the crucible is shown in Fig. 4.

It should be pointed out that the objective of the melting experiments was to prove the technical feasibility of the cold crucible for induction melting. Ingot quality was not considered to be of paramount importance in this investigation. In a commercial installation, larger diameter ingots would be produced by continuous extraction through the bottom of the furnace. With this arrangement, continuous feeding of the charge would be used and piping should no longer be a problem.

Conclusions

Research on the design and development of a cold crucible for induction melting reactive metals, such as titanium, has demonstrated that the process is technically feasible. This conclusion resulted from demonstrating that, by using an appropriate design, the effects of currents induced in the crucible can be reduced to an insignificant level. Vigorous stirring action occurs in the bath during melting and should assure superior chemical uniformity from single melting. In addition to its use for melting reactive metals, the cold-crucible process offers possibilities for vacuum melting specialty steels and super alloys.

Even though the technical feasibility of induction melting titanium in a cold crucible has been demonstrated, the technique would have little practical importance, if it were not economically competitive. Admittedly, it is often a difficult task to form reliable cost estimates of any new melting process. For one thing, the actual costs depend considerably on local conditions. It would be especially unreliable to try to make specific estimates concerning the commercial costs of a melting process based merely on laboratory experiments. However, a careful examination of the features of the cold-crucible induction process indicates that, although power and water costs may be somewhat higher than for competitive processes, other potential advantages, such as single melting, could offset much of this. The process appears to offer commercial merit. A primary objective of the present pilot-plant program is to evaluate more accurately the factors that will determine the commercial prospects for the process.

PREVENTING HYDROGEN EMBRITTLEMENT OF TANTALUM

Purity, history, source, and heat-treatment have no apparent influence on the susceptibility of tantalum to hydrogen embrittlement in an aggressive reducing-acid media. However, contact of tantalum with an extremely small area of platinum appears to be a particularly effective method of preventing embrittlement.

by C. R. Bishop and Milton Stern

One of the most versatile corrosion-resistant metals known, tantalum, and its behavior in a wide variety of environments has been well described.[1-11] However, in spite of its excellent record as a corrosion-resistant material in corrosive aqueous media, tantalum is susceptible to hydrogen embrittlement.[8,9,10,12] This susceptibility to hydrogen embrittlement does not imply that tantalum has a greater inherent tendency toward hydrogen damage than do most other metals. On the contrary, its remarkable corrosion resistance permits it to be exposed to environmental conditions which are far too extreme for other metals.

Tantalum absorbs gaseous hydrogen over a wide range of temperatures, and it is reported that the metal becomes brittle when rapidly deformed in an atmosphere of hydrogen at room temperature.[14] When tantalum is used in a corrosive environment, hydrogen may be generated on the metal surface by a corrosion process, by cathodic charging, or by galvanic coupling. Damage from galvanic coupling may be avoided by electrically insulating the tantalum from the remainder of the apparatus, but this is not effective when the embrittlement is caused by corrosion of the tantalum.

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The exact mechanism by which atomic hydrogen enters and embrittles tantalum is not well understood. However, it is well known that hydrogen will usually dissolve in a metal by dissociating into protons until the solubility is exceeded and a hydride forms. Hampel[4] indicates that the hydrogen expands the lattice creating stresses which cause brittleness.

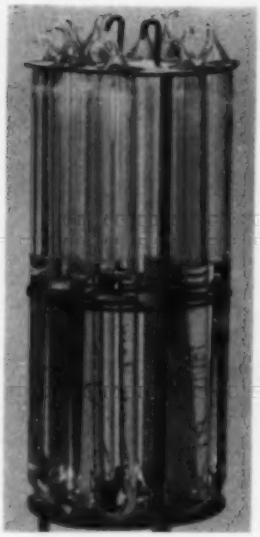
Since only reagents which do not contain strong oxidizing agents produce embrittlement, it was convenient to test the metal in concentrated hydrochloric acid at 190°C. A test period of 70 to 90 hr was usually sufficient for embrittlement to take place.

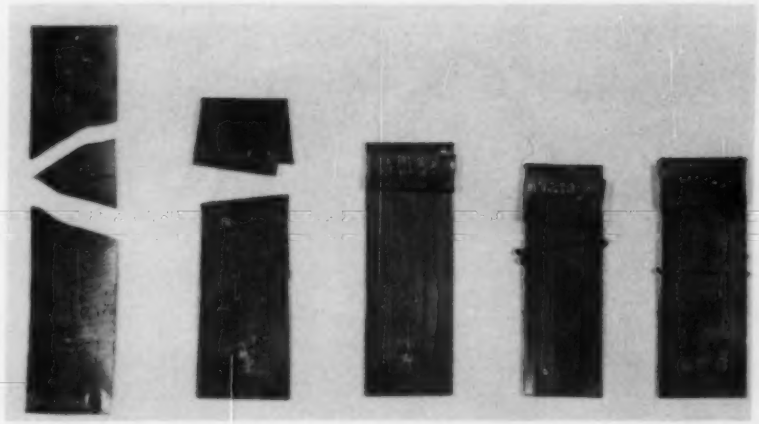
In addition to electrical insulation as a method of prevention, it is also possible to prevent hydrogen from entering the tantalum by electrochemical means.[4,13] However, these methods usually involve more difficulties than can be tolerated in a plant operation.

Table I. Influence of Contact with Noble Metals on the Hydrogen Embrittlement of Tantalum in Concentrated Hydrochloric Acid at 190°C[a, b]

Noble Metal		Spot Welds 0.01 In. Diam No. of Spots per Sample					Foil 0.1 Sq In. No. Spots			Surface Plated, Area Plated					Powder Rubbed on Surfaces	0.005 g Metal as Chloride in Sol'n
		0	1	2	3	6	0	1	4	0	¼	½	All	All Scratched		
Platinum	Results of bend test	E	OK	OK	OK	OK	E	OK	OK	E	OK	OK	OK	OK	OK	OK
	Corr. rate	12.0	10.1	8.37	8.54	10.0	12.0	8.61	—	12.0	15.0	13.1	13.1	13.2	—	7.65
Palladium	Results of bend test	E	—	OK	OK	—	E	OK	OK	E	—	OK	—	OK	OK	OK
	Corr. rate	12.0	—	9.92	8.25	—	12.0	9.34	7.58	12.0	—	9.36	—	8.24	—	11.0
Gold	Results of bend test	E	—	—	—	—	E	OK	OK	E	OK	OK	—	—	OK	OK
	Corr. rate	12.0	—	—	—	—	12.0	—	—	12.0	8.24	9.75	—	—	—	11.8
Iridium	Results of bend test	E	—	OK	OK	OK	E	OK	OK	—	—	—	—	—	OK	OK
	Corr. rate	12.0	—	9.72	8.45	11.0	12.0	13.3	7.97	—	—	—	—	—	—	11.3
Rhodium	Results of bend test	E	OK	—	—	OK	E	OK	OK	—	—	—	—	—	OK	OK
	Corr. rate	12.0	9.92	—	—	8.85	12.0	—	—	—	—	—	—	—	—	9.21
Osmium	Results of bend test	E	—	—	—	—	E	—	—	—	—	—	—	—	OK	—
	Corr. rate	12.0	—	—	—	—	12.0	—	—	—	—	—	—	—	—	—
Ruthenium	Results of bend test	E	—	—	—	—	E	—	—	—	—	—	—	—	OK	OK
	Corr. rate	12.0	—	—	—	—	12.0	—	—	—	—	—	—	—	—	11.6
Rhenium	Results of bend test	E	—	—	—	—	E	—	—	—	—	—	—	—	OK	OK
	Corr. rate	12.0	—	—	—	—	12.0	—	—	—	—	—	—	—	—	13.5
Silver	Results of bend test	E	—	—	—	—	E	E	E	E	—	—	OK	—	—	—
	Corr. rate	12.0	—	—	—	—	12.0	13.7	11.7	12.0	—	—	10.1	—	—	—

[a] Unless otherwise stated tests made on commercial, annealed sheet of ~0.6 sq in.
[b] Corrosion rates expressed as mils per year.
E Embrittled—cracked when bent.
OK No signs of embrittlement—sample bent 180°.





Left, Nest of heavy-wall glass tubes containing samples and corrosive media sealed and ready for test in autoclave. Above, Specimens of cold-rolled, high-purity tantalum tested in concentrated HCl at 190°C for 329 hr, followed by a bend test. A—plain specimen, very brittle. B—specimen with 0.02-in. diam rivet of Pd, also brittle. C—specimen with 0.02-in. diam rivet of Pt, remained ductile. D—specimen with strand of Pd wire, remained ductile. E—specimen with strand of Pt wire, remained ductile.

Two apparent approaches to prevent embrittlement are: 1) metallurgical modification of metal's structure, i.e. increase hydrogen solubility, or 2) surface treatment. Attempts at altering the structure by vacuum annealing and alloying with oxygen, carbon, iron, silicon, nickel, columbium, titanium, or tungsten did not have any beneficial effect in preventing embrittlement. However, efforts to prevent the phenomenon by surface treatment were more fruitful.

Surface treatment

This method involves contacting tantalum with another metallic element which has a low hydrogen overvoltage and which is electrochemically cathodic to tantalum in the same environment. The relatively wide difference in hydrogen overvoltage between tantalum and the platinum group metals[16,17] suggests that the noble metals as a group would best serve this purpose. Contact can be made by riveting, welding, electrodeposition, or by merely rubbing noble metals on to the surface of the tantalum.

The effects of various noble metals on hydrogen embrittlement are illustrated in Table I. Platinum is of interest because of its particularly low hydrogen overvoltage and excellent corrosion resistance. Although palladium generally exhibits a slightly higher hydrogen overvoltage than platinum, it is of interest because its lower cost could be important in commercial application.

For a more accurate evaluation, it was found necessary to define in a quantitative manner the area ratios which are critical for protection. Exposure at 190°C for over 1000 hr at the unusually small area ratio of 10,000 to 1 (Ta to Pt) resulted in no damage through embrittlement. In all tests in concentrated HCl, platinum was effective in eliminating embrittlement. Palladium was not as effective as platinum, requiring a larger contact area. In concentrated HCl, geometry factors did not appear critical. Results indicated that a small spot of platinum at one end of a tantalum strip protected the other end which was about 6-in. away.

A rather unusual observation, is that even small traces of platinum are effective over a long period of time, even though the corrosion resistance of Pt it not considered good in strong HCl solutions at high temperatures. Further investigations showed that a mutual effect exists, and when platinum is in contact with the tantalum, the corrosion rates of both metals decrease.

Conclusions

It appears that platinum contact to tantalum as a means for prevention of embrittlement has been effectively evaluated in laboratory tests. An important finding is that platinum is not significantly attacked when in contact with tantalum. The method should broaden the useful applications of tantalum, a factor which is particularly important at a time when chemical industry processes are utilizing higher temperatures and generally more aggressive conditions. Additionally, since the method is relatively simple, it seems likely that it could be applied in many cases in order to make existing equipment more versatile and capable of handling future operating requirements.

The authors have applied for patent protection covering this development.

References

[1] G. A. Nelson: Corrosion Data Survey, 1960 edition, *Shell Development Co.*, Emeryville, California.

[2] H. H. Uhlig: Corrosion Handbook, *John Wiley & Sons*, 1948.

[3] F. S. Badger: High Performance Materials, *Ind. & Eng. Chem.*, vol. 50, 1958, p. 1608.

[4] C. A. Hampel: Corrosion Properties of Tantalum, Columbium, Molybdenum, and Tungsten, *Corrosion*, vol. 14, no. 12, 1958, p. 557.

[5] N. P. Inglis, and J. P. Cotton: Corrosion Behavior of the Newer Metals, *Corrosion Prevention and Control*, vol. 5, no. 73, 1958, pp. 59-63.

[6] F. G. Cox: Tantalum as a Corrosion Resistant Material, *Corrosion Prevention and Control*, vol. 5, no. 44, 1958.

[7] D. F. Taylor: Acid Corrosion Resistance of Tantalum, Columbium, Zirconium, and Titanium, *Ind. & Eng. Chem.*, vol. 42, 1950, p. 639.

[8] L. R. Scribner: *Chem. Eng.* vol. 57, Nov. 1950, p. 255; vol. 58, Feb. 1951, p. 243, Apr. 1951, p. 214, May 1951, p. 251, June 1951, p. 224, Aug 1951, p. 228, Oct. 1951, p. 264, Nov. 1951, p. 300.

[9] M. G. Fontana: Corrosion Resistance of Tantalum, Columbium, Zirconium, Tungsten, and Molybdenum Metals, *Ind. & Eng. Chem.*, vol. 44, 1952, p. 71A.

[10] A. Percy: Tantalum, *Chem. Eng.*, vol. 59, 1952, p. 250.

[11] W. E. Lusby, Jr.: Titanium, Zirconium, and Tantalum for Control of Corrosion, *Corrosion*, vol. 13, no. 10, 1957, p. 56.

[12] G. L. Miller: Tantalum and Niobium, *Academic Press, Inc.*, 1959, p. 439.

[13] D. P. Smith: Hydrogen in Metals, *The University of Chicago Press*, 1948.

[14] A. Clauss and H. Forestier: The Brittleness of Tantalum in the Presence of Hydrogen at Ambient Temperatures, *Comp. Rendus*, vol. 246, 1958, p. 3241.

[15] H. Krekeler and H. Schiecht: Protecting Tantalum from Electrolytically Developed Hydrogen, German patent 719, 651, Mar. 1942 (C.A. vol. 37, 1941).

[16] E. Palmaer: Hydrogen Overvoltage, Particularly of Nickel, Tantalum, and Columbium, Comm. Tech. Etats et Propriétés Surface Métaux, *Journées Etats Surface*, Paris, Oct. 1945, p. 266; 1946, pp. 236-271 (presented in Chem. Abstracts, vol. 42, p. 3677).

[17] J. O'M. Bockris: Electrolytic Polarization—The Over Potential of Hydrogen on Some Less Common Metals at High Current Densities—Influence of Current Density and Time, *Trans. Faraday Soc.*, vol. 43, 1947, p. 417.

COLORADO SCHOOL OF MINES RESEARCH FOUNDATION

A brief description of a non-profit organization whose facilities, "now constitute probably the most comprehensive laboratory and pilot plants for research for the mining industry available in the country".

Since 1949, the Colorado School of Mines Research Foundation has been serving the mining and minerals industry with the accumulated knowledge and experience of its scientists and engineers and with its extensive pilot-plant and laboratory facilities. The scope of its operations has since broadened into the physical, chemical, ceramic, metallurgical, and nuclear fields. A completely separate, independent, non-profit corporation, the Foundation is joined traditionally and, to some extent, physically to the Colorado School of Mines.

The Research Foundation is well organized to work with its sponsoring industries. It can conduct research, either independently or in conjunction with the sponsor's engineers on a problem from an original idea through to its application in an industrial plant. Practically all sponsored work undertaken by the Research Foundation is of a confidential nature, and results and reports pertaining to the work are strictly the property of the sponsor.

Although the majority of its projects involve industrial research, the Foundation is actively engaged in Government contracts, and independent developmental research with broad and beneficial applications. Cost of research work completed during the year 1959-1960 amounted to $1.4 million. Of this amount, approx 14 pct was for Federal and Colorado State government projects, while the balance was for industrial concerns.

As the year ended there were some 125 full-time and 25 part-time employees on the payroll of the Research Foundation. In addition, the Foundation retains faculty members of the School of Mines as

consultants for special projects. Graduate and undergraduate students are employed as technicians and supporting workers.

Organization

The Colorado School of Mines Research Foundation is under the direction of E. H. Crabtree, who has guided the organization through its growth and development since 1955. Before assuming this office, Mr. Crabtree was deputy manager of the Atomic Energy Commission in Grand Junction, Colo. He is a past chairman of the Minerals Beneficiation Div. of the Society of Mining Engineers of AIME.

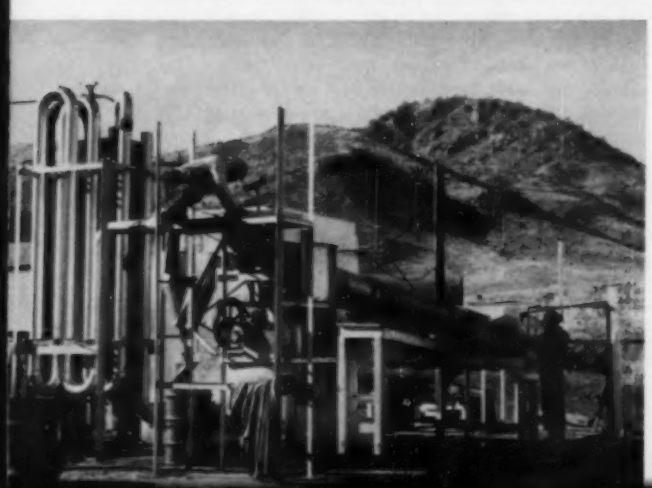
Under Mr. Crabtree's direction are the four divisions of the Foundation: the Mining Division, headed by Fred L. Smith; the Chemistry and Chemical Engineering Division, headed by C. J. Lewis; the Metallurgical Division, headed by F. T. Davis; and W. F. Anderson in charge of Business Operations.

Metallurgical Division

The Metallurgical Division is concerned with developing producing plants for the metallurgical industry. Its contributions to basic knowledge in the fields of metallurgy and ore dressing are inevitable by-products of its work on specific industrial problems, but the greater proportion of the work in the Division is applied research and process development.

Laboratory facilities include six general-purpose bench laboratories for all types of ore beneficiation and hydrometallurgical research. In addition, special laboratories include a magnetic and dry concentration laboratory, and a laboratory having a controlled atmosphere for research on soluble ore materials, such as potash. One entire building is devoted to iron-ore beneficiation facilities, and it contains seven well-equipped laboratories for this specific purpose. A large laboratory is available for metals research and the solution of physical metallurgy problems, and two laboratories are in operation for sample preparation. Also, there is a pilot crushing plant which includes a primary gyratory crusher, a cone crusher, an impact crusher, screens, continuous sampling apparatus, and its own materials handling equipment.

There are approx 20,000 sq ft of floor space available for the erection of all types of beneficiation and hydrometallurgical pilot plants, including flotation, magnetic concentration, gravity concentration, leaching, filtration, chemical processing as it relates to these processes, and combinations wherever applicable. Pilot plant and semi-pilot plant pyrometallurgical equipment includes rotary kilns, a multiple-hearth roaster, and a fluo-solids roaster. Bag houses, cyclones, scrubbers, and cooling trains are available in a flexible arrangement for research work involving this equipment.



The ultimate product of the Metallurgical Division is a successful commercial metallurgical plant operating on a sound economic basis. The efforts of the engineers and technicians of the Division have resulted in many new plants producing potash, phosphate, uranium, fluorite, rare earths, lead, zinc, and other products. A considerable amount of successful work has been accomplished for the improvement of existing plants for producing copper, calcite, gold, silver, iron, lead, zinc, wollastonite, tungsten, potash, uranium, manganese and molybdenum.

In the field of liquid-liquid extraction, the Foundation has pioneered in the study of applications of many new organic compounds which may be used to recover purified metal concentrates from both acidic and alkaline leach solutions. Some of these extraction processes are now in commercial use by uranium mills. Other developments include processes for the recovery of columbium, molybdenum, thorium, and vanadium.

The development of gaseous reactions for the recovery of metals directly from dry ores or concentrates may well prove significant in the field of metal recovery technology. The Foundation has developed new techniques which render gaseous chlorine reactions selective toward some metals.

Research Foundation personnel have worked with the Navy in the field of physical metallurgy, particularly on the production of ductile molybdenum and on dislocations in metals.

The Metallurgical Division is capable of conducting research from the first examination of an ore to determine its potential processing qualities up to and including studies of problems of operating plants or the planning and design of new plants. The Division can conduct market studies for potential products, complete process development in the laboratory and pilot plant, make flowsheet recommendations, and accomplish economic studies including predesign capital cost estimates and operating cost studies. Consultation can be provided during the design, construction, and operation phases of an enterprise. Moreover, research can be conducted with regard to the development of metallurgical equipment, and new uses for metals, alloys fabricated shapes, and mineral products.

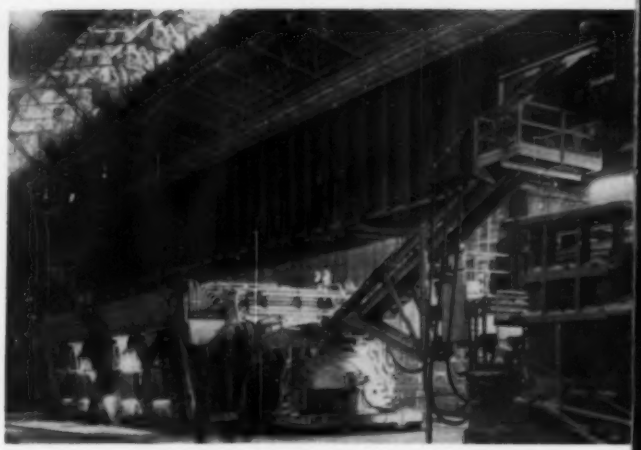
Continuing service

The activities of the Metallurgical Division have been described in some detail, but it should be emphasized that considerable work of great importance to the mineral industry is also being undertaken by the Mining and the Chemical divisions. All of this research work and the capital improvements to the Foundation's facilities have been self-supporting and without cost to the State of Colorado, which supports the School of Mines.

The 1959-1960 Annual Progress Report of the Colorado School of Mines states that the Research Foundation's "contributions to the mineral industry and to the School make its progress a matter of great interest to the annual affairs of the School of Mines". And that, "The facilities of the Research Foundation now constitute probably the most comprehensive laboratories and pilot plants for research for the mining industry available in the country."

THE AJAX FURNACE AND PROCESS

by A. Jackson



The Ajax process—making use of oxygen on a 100-pct hot-metal charge—has shown that it can compete with any existing process using phosphoric iron and making varied qualities of steel. Scrap used by the plant's former open-hearth practice is to be transferred to a new electric-furnace plant described in the December 1960 issue of JOURNAL OF METALS.

The Ajax furnace was designed, and the process formulated, in 1957 following a series of preliminary experiments on the application of intensive oxygen lancing to the production of steel from phosphoric pig iron made from indigenous British ores at the works of the Appleby-Frodingham Steel Co. This iron, containing some 1.3 pct P as it leaves the blast furnaces, has for over 50 years been converted to steel in large tilting furnaces, using only the circulating scrap arising from the manufacture of structural steels.

After the experiments, consideration was given to two possibilities: a) to use oxygen for bath lancing to accelerate production in the existing open-hearth furnaces, or b) to construct a furnace which would basically operate an oxygen process designed to have the maximum thermal efficiency, but to retain the characteristics of the open-hearth for fettling and final refining of the charge. The latter was chosen, and the furnace designed to give high operational rates when lancing with oxygen, but to have only a relatively moderate output rate should the oxygen supply inadvertently fail.

The critical areas of the furnace were based on theoretical calculations, and when the whole of the proposals were assembled, they constituted a unit which, in total, was unlike any furnace of which the author had knowledge. To distinguish this from the standard process and plant, the code name Ajax was adopted for record and discussion purposes. The salient features were as follows:

1) Minimization of air infiltration from the furnace to the chimney—the ports, uptakes, slag pockets, regenerators, and flues to the waste heat boiler are completely steel encased; bolted air-tight lids are used on all manholes and repair openings; and the joint between the port end and tilting hearth has machine-faced water-cooled surfaces, continuously pressed into contact by mechanical pressure applied to the movable port end;

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2) Maximum use of insulation—ports, uptakes, slag chambers, regenerators, and flues are insulated with both low and high temperature insulating materials;

3) Critical areas for gases—very small when compared with those of open-hearth furnaces designed to achieve similar productions—the outlet from the furnace hearth is only 5-ft in diam (area 19.5 sq ft), while the regenerator has a diam of 10-ft inside the brickwork, giving an area about 1/6 of that of a normal open-hearth with gaseous velocities proportionately higher; adequate cleaning is relatively simple with this small cross-sectional area of checker-work;

4) Oxygen admitted to the hearth itself (a) for combustion through the water-cooled burners, (b) through a water-cooled lance, or (c) mixed with air in the steel-clad regenerator system which prevents any escape to atmosphere; and

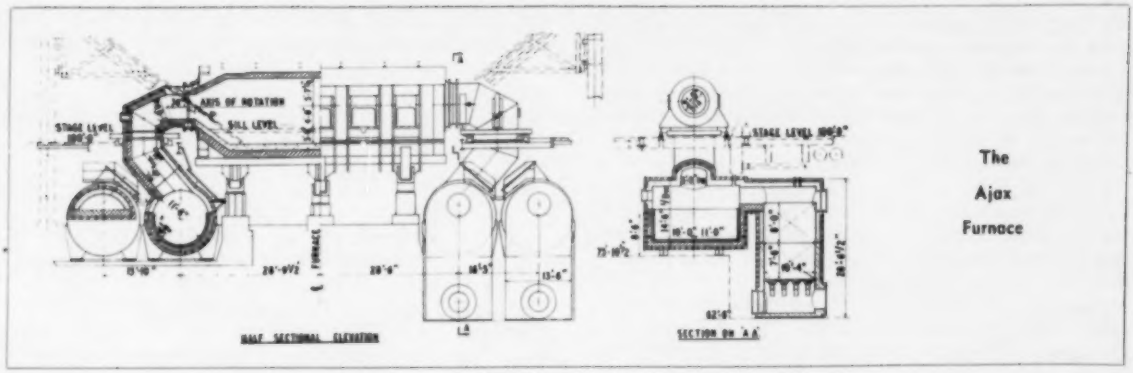
5) Slag pockets and regenerators enclosed in cylindrical steel shells and strong enough to be self supporting—they are also prefabricated and partially lined, thus enabling furnaces to be reconstructed on Ajax principles very quickly.

These factors were intended to:

a) Provide hot or oxygenated air to consume the CO evolved from the bath in the furnace hearth itself, thus making available for steelmaking the maximum amount of the heat potential of the elements eliminated from the hot metal—the heat remaining should be used with minimum loss in the waste heat boiler;

b) Minimize the size of the fume cleaner and fans, by avoiding infiltration; and

c) Allow ports and uptakes to be changed by overhead crane without losing production, also provide alternative slag pockets and regenerators so that the availability of the furnace is increased because it only need come off production to repair the hearth itself; the below stage structure can be cleaned and repaired while the furnace remains in full production.



The Ajax Furnace

The final design had the following characteristics:

1) The fuel was to be cold coke-oven gas, admitted through water-cooled burners located in each corner of the tilting furnace hearth. Oxygen might be admitted through two inlets, below each gas orifice. The maximum thermal input was to be 55 to 60 million Btu per hr.

2) The calculated theoretical output was 7250 tons per week, when using air only for burning the evolved CO; the record to date is 6653 tons.

3) The water-cooled lance was to be inserted at an angle through the furnace end in such a position that it did not interfere with tilting the furnace. It was to be operated by push button from a central control position, and the oxygen valves were operated by compressed air assisted valves. The lance was to be capable of deep immersion in the liquid bath.

4) All furnace controls were to be push-button operated from the central panel, which also was to carry all necessary indicating instruments for furnace operation. Recording instruments were to be housed in an air-conditioned cubicle behind the control panel.

The furnace designed to this specification has proved satisfactory and has been repeated in two furnaces subsequently built.

The Ajax Process

Immediately after tapping has been completed, the furnace contains 20 tons or more of steel and the slag which is used for refining the previous charge. This slag contains some free lime and has an iron oxide content related to the quality of the steel just tapped. But this iron is not lost, and the yield is superior to processes in which the finishing slag is tapped with the steel. This advantage is an important one, especially if the furnace is producing dead soft steels which usually have a high content of iron in the slag.

Additional limestone (5 tons) and feed ore (12 tons) are added in the quantities estimated to be necessary to achieve the bulk of the refining of the subsequent charge. Fettling follows, and is *burnt in* by fuel firing during this period. This operation also facilitates some solution of oxides and lime in the liquid slag already present, thereby forming the oxidizing slag necessary for early removal of phosphorus from the metal to be charged.

Molten metal is next added, and as soon as a sufficient quantity is present to form a liquid bath, fuel is cut off, the oxygen lance inserted, and refining commences, although charging has still to be finished.

All iron passes through an active mixer to which is added approx 50 lb per net ton each of limestone, feed ore, and pitside or other *dirty* plant scrap. Table I shows the total raw materials charged into the Ajax furnace together with the analysis of the blast-furnace hot metal and the mixer metal.

About 30 min after charging is completed, the analysis of the charged metal is received and the requirements of lime, feed ore, and oxygen are calculated to bring the bath to about 1.0 pct C and 0.1 pct P. Any additions necessary to the materials already charged are now made. The oxygen requirement is indicated on an integrator, and the volume recorder.

The furnace lances are reversed every 20 min (or when the regenerators reach 1350°C) until the integrator signals by light and sound that the calculated volume of oxygen has passed into the charge. The furnace condition is now examined; the metal temperature taken along with samples of the slag and metal.

The furnace is tilted and the exhausted slag teemed off; it contains 16.5 pct to 19.5 pct P_2O_5 and some 8 to 10 pct SiO_2.

By the time the slag is removed, the analyses of slag and metal have been returned, and lime is charged according to normal slag-control procedure. The oxygen required to bring the bath to about 0.30 pct C above specification is calculated, and this quantity is subdivided between ore and gaseous oxygen in accordance with the bath temperature at that time. The objective is to ensure that the temperature, when lancing ceases, is that required for satisfactory tapping.

When the prescribed quantity of oxygen has been blown, oxygen lancing ceases, and fuel firing is resumed. The charge is sampled using carbometer, combustion, or quantovac, and the furnace is tapped by removing two 100-ton ladles of steel in quick succession by tilting the furnace. No slag is removed, and the cycle recommences.

This method of operation minimizes iron losses, and produces a slag rich in phosphorus, and saleable after fine grinding as an agricultural fertilizer. It also allows 100 pct molten phosphoric iron to be used to make steel of all qualities in a manner which is highly efficient metallurgically, because slag production is a minimum, and it is not removed when it is hottest and contains the maximum iron oxide content.

Operating modifications

Certain operating modifications are used for various steel qualities. The simplest is the manufacture of dead-soft rimming steel in which oxygen blow-

ing frequently continues even during slag removal, until the furnace is about to tap.

For *catch carbons*, oxygen lancing is interrupted and fuel firing resumed when the charge is *clear* melted. Time is allowed for foaming to subside and the metal to come to equilibrium with the slag, which is then removed as completely as possible. If this is not done at that time with this phosphoric iron, rephosphorization will probably occur later in the process. Oxygen blowing, without fuel, is resumed, and the additions necessary to form the new slag are added. Blowing continues until the bath carbon is about 0.30 pct above final specification, after which refining is completed, and the charge is prepared for tapping with fuel firing. If low phosphorus, (0.020 pct) dead soft steel for *extra* deep drawing is required, then the same precautions at *slag off* are taken as for *catch carbons*. For normal soft steel, the phosphorus falls below 0.040 pct without special precautions.

Sulfur elimination

Sulfur is positively removed during lancing, and the final figure can be brought down to a specially low level by progressively adding lime during the oxygen blow after slag removal.

Sulfur balances have been made which show the gain or loss of sulfur to the system (including sulfur absorbed into the slag from the gases) during operating conditions over long periods; they are as follows: a) normal open-hearth operation using *dirty* coke-oven gas and creosote pitch, b) normal open-hearth operation using desulfurised coke-oven gas and creosote pitch, and c) Ajax furnace operation using *dirty* coke-oven gas when charging and refining only. The figures are shown in lb per 100 tons of metal.

	To Slag off	Refining	Total
Normal (a)	+18	+2.7	+20.7
Desulfurised gas (b)	+5.4	−8.1	−2.7
Ajax (c)	−9.9	−23.4	−33.3

These experiments indicate the considerable amount of sulfur which leaves the system during oxygen lancing and accounts for the high sulfur content of the oxide dust from the fume cleaner when fuel is not passing into the furnace.

Production rates

Production rates for the last 16 months are as follows:

Number of campaigns	4
Production per campaign	108,200 tons
Production per working week	5,152 tons

These figures are from two furnaces, one a modern all-basic furnace which showed an increased production of 51 pct after conversion, the other a 42-year old silica furnace which gave an increased production of 102 pct. The campaign length has no special significance, as the *below stage* part of the furnace is repaired while the furnace is working.

Oxygen and fuel consumption

The consumption of fuel and oxygen are interrelated. For ordinary dead soft rimming steel, oxygen is higher and fuel lower, but when making catch carbon steel the opposite is found to be the case. In the figures below N furnace in one melting shop was making softer steels than B furnace in a different department.

	Oxygen, cu ft/ton ingots	Fuel, Btu x 10^6 per ton ingots
B Furnace	1,207	0.921
N Furnace	1,382	0.761

Oxygen for combustion, included in these figures, is about 160 cu ft/ton ingots.

Fuel consumption for normal open-hearth practice was 4.0 million Btu per ton of ingots, with about the same quantity of oxygen used for combustion. The fuel consumption has, therefore, shown a reduction in the Ajax furnace of nearly 80 pct of former practice, against which must be set the cost of the extra oxygen used.

Refractories

The original Ajax furnace was all basic, i.e. roof, offtakes, slag pockets, and the upper half of the regenerator brickwork. Experience quickly showed that the slag pockets and regenerators were not likely to experience the uncontrolled high temperatures which it was believed were possible; therefore, in subsequent furnaces, the regenerator chambers and the top half of the slag pockets have been lined with silica bricks, while the upper layers of the checkers are now 42 pct alumina firebricks.

The roof was fired chrome-magnesite brick. In the early days, its wear was rapid because of the enormously high temperatures (over 1900°C by thermocouple) above the point of impact of the lance and the slag and metal splash. Thus, patching was required every 10 to 14 days, and roof life was only 26 to 28 days.

The rate of oxygen input was materially reduced and modified lance types and impact angles were used under trial conditions until optimum operating rates were achieved. The unit roof life rose to 42 to 48 days with some improvement in annual production.

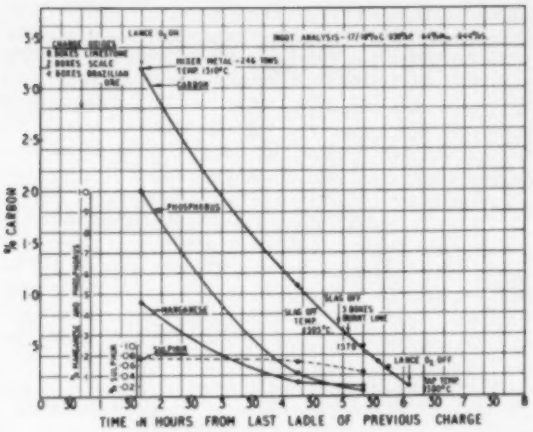
The roof is 15 in. thick and is built on rigid skewbacks as formerly used for silica roofs. However, it is held down against movement when tilting by seven small joists running the full length of the furnace hearth. When the heating up temperature of a new roof reaches 1100°C, the hold-down bolts are screwed down to make contact with the joists and thereby prevent any further rise of the roof during heating up or in subsequent steelmaking.

In September 1959, a new type of roof installation

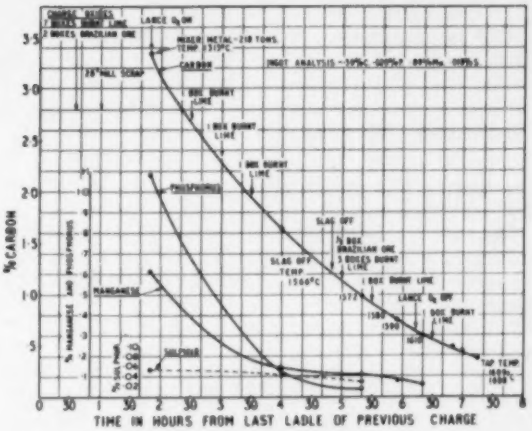
Table I. Charge for Ajax Furnace

Materials charged, lb/ton ingot	
Mixer Metal	2120
Finishings	21
Ore	190
Lime	48
Limestone	85
Dolomite	58

Analyses, Pct	Blast Furnace Metal	Mixer Metal
C	3.77	3.84
P	1.31	1.12
Mn	0.92	0.47
S	0.055	0.05
Si	0.63	0.24



Normal Ajax charge for structural steel.



Catch-carbon cast from the Ajax furnace.

was tried. It increased roof life to 80 to 84 days and has, therefore, become standard practice. This roof consists of a checker pattern of alternate magnesite and chrome magnesite bricks interleaved with steel sheets. Its principal object is to neutralize the hot face expansion of chrome-magnesite by the high-temperature contraction of the magnesite. It was also found that, while each type of brick tended to crack in use, these cracks were not the same distance behind the hot face in each kind of brick; thus, the tendency for a whole slab to peel off, as found in chrome magnesite roofs, was not observed in this checker-board mixture, which exhibited uniform surface wear without spalling. A further, though yet unmeasured, increase in life is expected from the increase in roof rise which now has been raised to 2.75 in. per ft of span; almost 3 in. can be achieved later, if necessary. The full effect of the use of the checker pattern roof is not included in Table II which compares the last four Ajax campaigns with former practice using basic roofs.

The reduction in refractory consumption is principally from uptakes, slag pockets, and regenerator chambers. This reduction arises partly from the arrangement whereby the maximum checker temperature is controlled at 1350°C and also, to a significant degree, from the use of interchangeable ports, offtakes, slag pockets, and regenerators. In normal open-hearth practice, the necessity of getting the furnace quickly back into commission and ensuring that it lasts through a long campaign involves mechanical wrecking, blasting, and the replacement of important quantities of refractories not already worn out.

In the Ajax furnace, the slag pockets and regenerators are changed on a regular cycle of 4 weeks. After making all allowances for this changeover, including raising to operating temperature, the availability of the *below stage* structure averages 99.14 pct.

Table II. Refractory Consumption of Ajax Vs. Open-Hearth Practice Using Basic Roofs, lb per ingot ton

	Standard Open Hearth	Ajax Furnace
Silica bricks	13.27	1.19
Firebrick	5.18	1.47
Magnesite brick	1.70	1.91
Chrome magnesite	9.94	12.22
Total	30.09	16.79
Ingot tonnage	850,000	432,299

The spare furnace sections can be steadily repaired over 4 weeks if necessary. They are slowly cooled and wrecked with care. Furthermore, it is unnecessary to remove large quantities of undamaged brickwork to meet the prospective needs of a long campaign because the life is broken down into 4 week periods. Regarding the furnace-end offtakes, these are so easily changed that any partially worn-out end which appears likely to give a further week's life is put back when the hearth and roof are renewed; thus, the only part which now needs to be repaired at high speed is the body of the furnace itself.

Port ends, offtakes, slag pockets, and regenerator chambers are all well insulated. This leads to the possibility that when the basic lining wears thin it may suddenly collapse without showing hot on the outside. The life of the insulation will then be short; the steel structure will be rapidly burned through; and a changeover becomes necessary at some inconvenient time. To obviate this possibility, the temperature of the known critical parts is measured by contact pyrometer at intervals from 7 days upwards, depending on the expected life of the section under examination. The temperatures normally recorded vary from 120° to 150°C. As soon as they increase to about 275°C it is necessary to consider making a change within the next few charges. It is desirable to changeover at weekend under normal circumstances.

Iron losses and recovery

Recoverable iron losses from the furnace system fall into three groups: slag-pocket slag, flue dust, and dust from the gas cleaner. These materials contain in total 13.5 lb Fe per ton ingot, equal to 0.675 pct; all are returned to the blast furnaces.

In normal open-hearth practice no recovery is made from the slag-pocket slag, while a significant amount of oxide is lost in the waste gases leaving the chimney top; thus, the irrecoverable loss of iron is significantly greater than in the Ajax modification.

Gas cleaning is by dry electrostatic precipitation and is very satisfactory in giving an extremely clean stack. Details are as follows:

NTP gas volume	25,000 cu ft/min
Inlet temperature	250°C
Inlet dust concentration	7.0 grains N cu ft
Outlet dust concentration	0.05 grains N cu ft
Guaranteed efficiency	99.3 pct

The specific HT power consumption is 0.43 kw per 1000 cu ft per min.

The small size of the gas cleaner is possible because of the low infiltration resulting from the steel encasement of flues, regenerators, slag pockets, and furnace offtakes. The peak through-put of gases, which is actually during fuel firing, is about 20,000 cu ft per min.

Other methods of gas cleaning have been considered, but dry cleaning following cooling in a waste-heat boiler undoubtedly gives the most economic results. On the Ajax furnace, steam is made in the boiler and from evaporative steam cooling on the furnace. If this steam is assumed to have the same value per 1000 lb. as that produced by the Company's most efficient blast-furnace gas fired boilers, a credit is obtained which more than covers the total cost of operating the gas cleaner as well as the steam producing plant, thus also giving a useful return on this part of the capital expenditure.

Heat utilization and costs

The tabulation in Table III shows analysis of the heat utilization of the process based on the production of 1 gross ton of liquid steel as tapped.

The heat balance shows the thermal efficiency including heat recovery to be 75 pct. The open hearth and other oxygen processes may be capable of recovering more heat units in steam than the Ajax furnace because the latter endeavors to make the fullest possible use of the heat generated by the process in the furnace itself and to absorb any excess by the endothermic decomposition of ore. This is obviously desirable, since the aim of the process is really to make steel and not to make steam. The vessel is less compact than some of the other oxygen processes, and the external heat loss per ton would be expected to be higher. The use of insulated and cased structures has, however, kept these losses down to 12½ pct of the input heat (including losses from the flues and boiler). The retention of the open-hearth body does, however, enable production to continue at a much slower rate, if the oxygen supply should fail.

It should be noted that the efficiency of an open-hearth furnace using the same materials as the Ajax furnace would be some 20 pct lower or about 55 pct.

The average cost chargeable to capital for the conversions has been approx $6 per annual ton on the increased production achieved. The reduction in ingot cost has recovered this cost of conversion in well under two years. The major items of capital cost are the gas cleaning plant, the new slag pocket and regenerator chambers, flues, and uptakes.

It is estimated that, if Ajax furnaces were built on a green field site for the practice described, the capital cost would be between 60 pct and 65 pct of that required for equivalent production from the standard open-hearth furnaces. This difference arises from the increased production per unit, the ability to prefabricate almost all of the below stage structure, and the simple foundations.

A comparison of operation costs between open-hearth practice using the basic roof and the Ajax furnace under conditions existing at Appleby-Frodingham shows Ajax costs to be some 68 pct of those of the open hearth, with greatest economies in fuel and maintenance.

Conclusion

The Ajax process has now produced well over 1 million tons of ingots from the three furnaces already converted, the first conversion commencing at the end of 1957, the second in mid-1959, and the third in mid-1960. Another conversion is about to start, and within two years the total number operating will be eight, giving an increased annual production of 700,000 tons.

The operating cost (excluding raw materials) has been reduced to 68 pct of previous standard open-hearth practice. In addition, the cost of servicing the reduced capital invested will give a further reduction of about $1.5 to $2.0 per ton of ingots.

Further developments are expected, but even now the Ajax furnace can obviously compete closely in costs with any existing process using such high percentages of phosphoric iron and making mixed steel qualities as required to service the mills with hot steel on all possible occasions.

Readers may be interested to know how the mill scrap arisings are to be used, since the Ajax furnace is described as operating on 100 pct hot metal. This scrap is to be melted in 110-ton arc furnaces with transformers of 40,000 kva, using 100 pct scrap at another works of the Company. Details are given in a paper by Howes and Jackson published in the December 1960 issue of JOURNAL OF METALS.

Table III. Heat Balance—including boiler[a]

IN	Btu x 10^6 per ton tapped	pct	OUT	Btu x 10^6 per ton tapped	pct
Sensible heat in metal	11.43	30.40	Sensible heat in steel	12.88	34.21
Sensible heat in steam	0.09	0.23	Sensible heat of slag	2.67	7.09
Heat of combustion gases	8.67	23.05	Sensible heat in dust passing out of boiler	0.01	0.03
Net heat from combustion of metalloids:			Decomposition of limestone	0.82	2.18
C (to carbon dioxide)	10.81	28.74	Decomposition of oxides	4.32	11.49
P	2.66	7.06	Useful steam from evaporative cooling (167 lb/ton steel tapped)	2.09	5.55
Mn	0.74	1.97	Useful steam from waste heat boiler (434 lb/ton steel tapped)	5.43	14.40
Si	0.80	2.38	Cooling water and evaporative cooling losses	2.08	5.53
Heat of slag formation	2.32	6.17	Waste gases (sensible) leaving boiler	2.56	6.83
			Heat losses from furnace and boiler (difference)	4.76	12.69
Total	37.62	100.00	Total	37.62	100.00
			Efficiency: with evaporative cooling = 75.0%		

[a] Calculations based on long ton.

PHILADELPHIA AND THE METALLURGICAL SOCIETY, A smashing Fall Meeting!

It opened on Monday, the 17th of October, the Fall Meeting did. And the place was the ultra-modern Sheraton Hotel in the old and modern city of Philadelphia. Metallurgists from far and near were attracted to the meeting, held according to tradition, in conjunction with the National Metal Exposition and Congress.

Highlight of the opening day was the morning-afternoon symposium, Metallurgy in the Army, which provided extensive information on the Army's research and development program. A general review of the symposium, together with a summary of several of the papers presented is to be found elsewhere in this issue. At the Army Day Luncheon, John R. Townsend of the Office of the Director of Defense Research and Engineering spoke on *The Role of Metals in National Defense.*

Tuesday morning featured the 1960 Institute of Metals Lecture presented by N. F. Mott of University of Cambridge. Professor Mott spoke on *The Work Hardening of Metals.* The Lecture was printed in full in the December 1960 issue of TRANSACTIONS.

Tuesday afternoon brought forth a symposium on *Titanium Versus Steel and Aluminum in Pressure Vessels for Hydrospace, Aerospace, and Space.* Highlights of this symposium will be a feature of the March issue of JOURNAL OF METALS.

Fall Dinner

This and other sessions were followed by the Fall Dinner which began with a few drops of liquid-liquid entertainment and then moved to the Pennsylvania Room for the banquet itself. Dinner guests were welcomed in the spirit of Benjamin Franklin who with his key of metal on the end of the now famous kite provided the spark of discovery. American Society for Metals President, Walter Crafts, stressing united action of the two national societies in the metals field, commented that he was proud to wear badges of both the ASM and the AIME. Dr. Crafts also pointed with satisfaction to cooperation in regional meetings and student chapters. Carleton C. Long, President of The Metallurgical Society, had great praise for Robert Shearman, the Society's Secretary, as well as Joseph L. Gillson, *the workingest AIME President.*

Donald C. Rubel, vice president of the Board of Directors of City Trusts presented one of the 1960 John Scott Awards to Professor Frank A. Forward, head of the Department of Metallurgy at the University of British Columbia. The award, consisting of a copper medallion and a cash prize of $1000, was established in 1816 by John Scott, a chemist of Edinburgh, Scotland. It was presented to Professor Forward for the development of his process for the extraction of nickel and other metals from concentrates by pressure leaching with ammonia and water.

Toastmaster of the evening, J. H. Jackson, read a telegram of congratulations to Professor Forward from the Dean of Faculty of Applied Science of the University of British Columbia. He then introduced AIME President Joseph L. Gillson, who in turn presented to Leopold Pessel, chairman of the Philadelphia Section of AIME, a memento with congratulations to the section for having gone over the top in the building fund drive.

Speaker of the evening was Herbert Friedman of the U. S. Naval Research Laboratory who spoke on *The New Astronomy.* He pointed out that the sun is one of a hundred billion stars that make up our local galaxy . . . "a thin disc, 10,000 light years thick and 100,000 light years in diameter. The sun completes one revolution about the center of the galaxy in 200 million years . . . a cosmic year. The super-hot stars that inhabit the spiral arms were born from interstellar gas less than 1/100 of a cosmic year ago. The earth and sun are 25 cosmic years old, and the oldest stars are about twice as old again."

"The nucleus of the galaxy is a disc of neutral gas spinning with high velocity. It has a radius of somewhat more than 1000 light years and a thickness of about 500 light years with an average density of between 1 and 2 atoms per cc."

"The hydrogen expands outward from the center at speeds up to 100 miles per sec. The expanding arms carry away roughly 1 solar mass per year from the nucleus; this is equivalent to 200 million suns per cosmic year. Where does it all go and how does the nucleus continue to supply this enormous amount of gas? There is evidence that the galaxy is surrounded by a gaseous halo. One hypothesis suggests that this gas is drawn inward toward the nucleus by magnetic forces and then spreads outward through the spiral arms."

"Galaxies tend to be distributed in groups, sometimes as small as two or three, and sometimes as many as a thousand. The Hale telescope on Palomar can see out to 2 billion light years (3×10^{22} or 30 sextillion miles). One billion galaxies lie within that range."

Left, Donald C. Rubel presenting a John Scott Award to Professor Frank A. Forward. Right, Walter Crafts bringing greetings from the American Society for Metals.

"The galaxies move relative to each other within their particular groups. Sometimes two galaxies collide at high speed. The chance of two stars colliding is negligibly small because the stars are so small relative to interstellar distances. But the interstellar gas clouds are very extensive and do collide. When this happens the gas is stirred to violent turbulence and becomes extremely hot."

"What is the content of matter between the galaxies? According to Fred Hoyle, the brilliant English cosmologist, the average density of the universe is 3×10^{-30} grams per cc, or as he puts it 'about one hydrogen atom to a good sized suitcase."

Hoyle is one of the originators of the theory of continuous creation of matter. The newly created matter is postulated to appear as hydrogen atoms to keep the density of space constant in spite of the expansion of the universe. It requires the creation of about 1 atom per hundred years in volume as large as the Pentagon building. More recently, Gold and Hoyle have proposed that the primary particles created are not hydrogen atoms, but neutrons. Since the neutrons are unstable, they disintegrate almost immediately into protons and electrons but in the process release so much energy that the gas clouds get heated to temperatures as high as a billion degrees K. This heat makes the gas expand and since it fills the whole universe, the universe as a whole expands. To explain the formation of galaxies, Gold and Hoyle propose that some of the great clouds of cosmological gas radiate some of the heat away over the course of several billion years. As the temperature drops, the gas cloud will tend to condense. When it reaches a critical point where gravitational attraction between the gas particles is greater than their pressure to expand, the great cloud collapses forming a galaxy or a cluster of galaxies. The cooling process may be associated with the production of cosmic radio waves and the origin of cosmic rays. Another consequence of the cooling is the emission of x-rays. Many of the distant radio sources observed by radio astronomers may be indicative of a phase in the process of the formation of new galaxies."

Wednesday's program

On Wednesday the 19th of October, the IMD Refractory Metals Committee presented a status report on the Refractory Metal Sheet Rolling program. The Materials Advisory Board of the National Academy of Sciences has formed a panel, known as the Refractory Metal Sheet Rolling Panel, to serve as a technical advisory group. G. Mervin Ault described panel activities, and reports were presented on the status of two of the six subpanels. This part of the program was followed by a report on the status of the current contractors' activities which are coordinated by the Bureau of Naval Weapons. Although these activities are in a very early stage, they were thought to be of sufficient interest to present a report on their current status and some of the future plans of both the Panel and the contractors. At a later date, JOURNAL OF METALS expects to publish a report on the Refractory Metal Sheet Rolling program.

A highlight of Wednesday afternoon's program was the session on *Structural Materials in Cryogenic Design*—the initial program organized by the IMD Structural Materials Committee. R. E. Jacobsen of Boeing Airplane Co., compared cryogenic tank design at room temperature and temperatures close to absolute zero, while R. Markovich of The Martin Co. discussed material selection and insulating requirements of cryogenic tanks as a part of the missile structure. Stainless steel, aluminum, titanium, and magnesium are being considered in current designs. E. W. Johnson of Aluminum Co. of America pointed out that designing equipment for service in the

Left, AIME President, Joseph L. Gillson congratulates Leopold Pressel of the Philadelphia section for the section's subscriptions to the building fund. Right, John R. Townsend addressing the Army Day Luncheon.

cryogenic range of temperatures is not fundamentally different from designing for service in other ranges. It does however, require a shifting of emphasis among various design criteria. As their temperature is lowered, metals with body-centered cubic structure undergo a transition from ductile to brittle fracture behavior, while face-centered cubic metals do not.

The properties of high-strength structural alloys—such as cold-rolled and heat-treatable stainless steel, aluminum alloys, nickel-base alloys, cobalt-base alloys, and certain titanium alloys—used in aerospace vehicles at cryogenic temperatures were discussed by J. F. Watson of Convair Astronautics. Fracture strength and toughness of such alloys was considered by J. E. Srawley of the U. S. Naval Research Laboratory, while W. F. Brown of the National Aeronautics & Space Administration compared alloys presently used for LOX tankage with those being considered for advanced liquid-propellant rockets. The sharp-edge notch tensile test is used to evaluate the properties of materials in the cryogenic range.

The final day

Among other interesting sessions, Thursday the 20th of October brought forth *Engineering Fundamentals of the Rolling Process*, the first session to be sponsored by the IMD Shaping and Forming Committee. L. E. Coffin, Jr., of General Electric Research Laboratory summarized the present status of the theory of rolling. He used both classical plasticity analysis and slip-line field analysis to explain quantitatively separating forces, effect of tension, power requirements, residual stresses, spreading, fishtails and bullnoses, and non-uniformities and hardness variations arising during rolling. G. W. Pearsall of Massachusetts Institute of Technology discussed boundary conditions at the roll-material interface. He summarized the present state-of-the-art on causes and results of roll interface friction, including new experimental results. W. R. Hibbard, Jr., of General Electric Research Laboratory described structures and properties resulting from rolling. He showed the relationship between the rolling process, the slip systems of classical crystal mechanics, and the textures or preferred orientations observed in rolled and annealed metals.

Another Thursday feature was the annual Powder Metallurgy Luncheon. Speaker was John W. Weeton of the National Aeronautics & Space Administration who described to the audience how the use of tungsten whiskers imbedded in copper matrix could achieve tensile strength from 1 to 2 million psi needed for space applications. He pointed out as possible future applications of powder metallurgy, grids, turbine blades, and armature wires for space platforms. A typical example is a tungsten ionization grid through which ions pass from a cesium reactor. Pores of the grid are 1 μ in. diam, but they must not sinter shut despite a two or three year flight time. Mr. Weeton suggested that dispersion strengthened SAP may have the thermo-stability needed for many such applications in such long flights.

Some of the major features of the 1960 Fall Meeting have been sketched out, but these were by no means the only important symposia and papers. Additional information on these other features is available in the abstracts which appeared as a part of the Fall Meeting program in the September 1960 issue of JOURNAL OF METALS. Furthermore, it is anticipated that many of these papers will be published as articles in the TRANSACTIONS of The Metallurgical Society. **FWS**

ELECTRIC FURNACES, CLEANLINESS, AND BETTER STEELS

Eighteenth Annual Electric Furnace Conference breaks previous records with 1094 attendance!

Cleanliness or *Better Steels Through Better Quality* was the central theme around which was organized the Eighteenth Annual Electric Furnace Conference held from November 30 through December 2 at the Morrison Hotel in Chicago.

Welcoming the record-size gathering was G. C. Olson, chairman of the Conference Committee and 1961 chairman of the Electric Furnace Executive Committee. "Let's get together and solve our problems," suggested Mr. Olson as he stressed the conference's theme. P. R. Gouwens, 1960 chairman of the Executive Committee, added his welcome before registrants moved to the first session.

Non-Metallic Inclusions in Steel, the topic of the first conference session, got underway with a paper by W. D. Forgeng of Union Carbide Metals Co., on the subject, *Techniques for the Study of Nonmetallic Inclusions*. He pointed out that metallographic examination provides a rapid method for identification of many indigenous inclusions, particularly when special techniques, such as polarized light and dark field illumination, are used. With exogenous inclusions and some indigenous types, the additional information furnished by a study of the isolated inclusions by X-ray diffraction, petrography, and spectrographic or micro-chemical analysis, assists greatly in their identification and in the determination of their source.

D. C. McCarter, S. Ramachandran, and J. C. Fulton of Allegheny Ludlum Steel Corp., discussed *Inclusions in Stainless Steels*, calling attention to the fact that in the stainless steel industry, inclusions can be a particularly acute problem, since nonmetallics can contribute to a number of surface defects which mar the appearance of finished grade strip. The report concerned a study of refractory contamination from nozzles, nozzle wells, ladle brick, and stopper rods. By tagging the various refractories with chemical tracers, their influence on the inclusion content of stainless steels can be studied. Both ladle samples and finish-gage samples were examined by extraction and analysis of inclusions. The results showed that the maximum proportion of inclusions that could be traced to ladle refractories was about 14 pct. Finish-gage samples of both good and bad areas showed about the same degree of refractory contamination. Therefore, in normal teeming practice for stainless steels, refractory erosion does not account for changes in total inclusion level in finish gage strip.

In a paper entitled, *Inclusions in High-Temperature Alloys and Ferritic Steel*, A. Nagy and W. J. Pennington of Universal-Cyclops Steel Corp., stressed the very low inclusion levels required of such metals. Grades produced by vacuum induction melting normally can be melted with little or no contamination resulting from oxidation or slag-metal reactions that occur under normal air melting. But one disadvantage is that melting is done in a refractory contamination during vacuum melting, but it is dependent upon the quality of air-melted consumable electrodes.

Another paper from this session, *Quantitative Extraction of Non-Metallic Inclusions from Steel*, by H. Walz and R. A. Bloom of Timken Roller Bearing Co., was published in the December 1960 issue of JOURNAL OF METALS.

Ferroalloys and Steel Quality

Ferroalloy Quality vs Steel Quality was the subject of a controversial session on Wednesday morning. P. B. Dennis of Atlas Steels Ltd., Welland, Ontario, Canada, discussed the subject from a steelmakers' point-of-view, commenting that, "The ever-increasing demands placed on steelmakers to improve steel quality has made it necessary to investigate every possible source which may have a

Plenty of fun, as well as serious business! Below, G. C. Olson, 1961 Chairman of the Electric Furnace Executive Committee, presents a token of thanks to past-chairman, P. R. Gouwens.

bearing on the quality of their ultimate products." And, "... it has become apparent that the quality of the ferroalloys has some influence on the overall problem ...". Unfortunately, "... the steel industry has not published much data with regard to correlating the possible effects of ferroalloy quality on steel quality, even though individual steel companies may have established their own standards and are conducting investigations. At present, the efforts of several steel manufacturers are being directed to investigate this aspect with the ultimate intention to develop generally acceptable standards. It would be to the mutual benefit of both ferroalloy and steel manufacturers to cooperate and establish realistic standards which are both workable and within economical limits."

On the other hand, E. R. Saunders, W. D. Forgeng, and J. W. Farrell of Union Carbide Metals Co., in their paper, *The Formation of Non-Metallic Inclusions in Alloy Additives*, stated that "Experiments on laboratory and commercial-scale heats have shown little or no correlation between the types or amount of non-metallic matter in these alloy additives and the quality of finished steels." The authors stated further that, "Barring unusual conditions, it appears that the possibility of entrapping inclusions that may be present in alloy additives is remote. The primary effect of alloy additives on inclusion formation in steel results from major changes induced by the chemistry of the bath."

At this same session, E. R. Saunders, J. L. Lamont, and G. Porter of Union Carbide Metals Co., presented a paper entitled *Hydrogen in Alloy Additives* in which they state that, "It is estimated that less than 3 pct of the total hydrogen available in the production of a commercial heat of stainless steel is introduced by the alloy additives." The authors explained that, "Alloy additions, as compared to other sources of hydrogen in steelmaking operations, were evaluated in a hypothetical heat of 430 stainless steel. The total hydrogen available was estimated to be 112 ppm, about 10 times the solid solubility limit. Of the total hydrogen available, about 3 pct was from the alloy additives. The known final hydrogen range of 5 to 8 ppm is Type 430 stainless steel emphasizes that there must be low recovery from the various sources."

Phosphorous and Ferroalloys

During the past several years, the scope of the Electric Furnace Conference has broadened considerably. This trend continued in 1960 with the initial appearance on the program of papers on phosphorous production. J. C. Barber and M. M. Striplin, Jr., of the Tennessee Valley Authority described the *Handling and Utilization of Phosphorous Furnace Slag*, stressing that, "The deposition of the slag presents a problem in the phosphorous industry. ... At some plants the slag is discarded, while at others it is processed and sold." The authors gave detailed information of methods for water quenching the slag and its use in the production of lightweight concrete aggregate.

Arturo Chavez of the Electric Reduction Co. of Canada provided information on the *Operation of an Electric Furnace in Manufacturing Phosphorous*. He pointed out that, "The Tennessee Valley Authority has given a great technical advance to the use of the electrothermic process for the manufacture of phosphorous by the development work on electric furnaces which they started in 1934 and which is still being carried on today.

"As a result of these developments, the Electric Reduction Co. of Canada built another elemental yellow phosphorous plant at Varennes, Quebec, Canada, in 1952 with electric furnaces of 16,000 kw capacity."

"The electrothermic process to manufacture phosphorous consists of the reaction of a phosphate ore with coke and silica rock in an electric furnace. The element is recovered from the furnace by condensing its vapor ... liquid products are the slag and by-product ferrophosphorous, both of which are tapped from the furnace intermittently through two different tap holes."

"The ... three phase inline ... furnace consists of an oblong crucible fitted with a roof built of cast refractory with gas-tight plaster. The hearth is made of two layers of carbon blocks, 30 in. wide and 22 in. deep. The bottom section of the sidewalls, also made of carbon blocks, supports a fire-brick wall."

The crucible measures 36 x 20 ft, and it is supported by 12-in. I beams laid on a concrete foundation. The shell is made of steel, and it is completely water cooled by continuous sprays directed at the top part of the shell . . . . Openings are provided in the roof for three electrodes, twelve feed chutes, six poke holes, and a gas off-take."

In the well-attended ferroalloy session, detailed descriptions were given of the production of such alloys as low-carbon ferrochromium silicon and 75 pct ferrosilicon at the plants of Interlake Iron Corp. and Pittsburgh Metallurgical Co., respectively. These papers provided a great deal of information on the intricacies of production.

A number of other interesting technical sessions were held during the course of the conference. From these, the JOURNAL OF METALS expects to publish several papers during 1961, including *Treatment of Steel with Magnesium to Ease the Sulfur Problem* by W. B. Brooks; *Argon Casting for Improving Steel Quality* by M. F. Hoffman, P. G. Bailey, and R. L. W. Holmes; and *Manufacture of Simplex Ferrochrome by the Vacuum Process* by C. G. Chadwick.

Plant trips

The final day of the conference was given over to plant trips. Registrants could choose either the Ochiltree plant of Lemont Manufacturing Co., or the South works of U.S. Steel Corp.

At Lemont Manufacturing Co., the operations of three 20-ton electric arc furnaces were inspected. Reinforcing bars, flats, angles, and round bars are rolled in the mills of the plant. The firm was host at a Swedish Smorgasbord luncheon, following which Robert Kulp thanked the company on behalf of the visitors. He stressed the excellent layout of the plant and the intelligence of the guides in answering questions.

At the South works of U.S. Steel Corp., there are two 70-ton and one 90-ton electric arc furnaces. Vacuum degassing operations were witnessed, and visitors were escorted through the new 53-in. blooming mill, equipped with automatic controls and conveyors. On returning to Chicago, a buffet luncheon was served to all participants at the Sherry Hotel through the courtesy of U.S. Steel Corp.

Annual Dinner

A highlight of the conference was the Annual Dinner held on Thursday, December 1, at the Constitution Room of Chicago's Morrison Hotel. President of The Metallurgical Society, C. C. Long spoke briefly and recognized with pleasure the large audience that was attending the conference. AIME President, Joseph L. Gillson, commented that of the many AIME meetings that he had attended around the country, this meeting was one of the most congenial.

Toastmaster of the evening, Foster C. Brown, Jr., president of Lemont Manufacturing Co., introduced Charles J. Hunter, general superintendent of the South works of U.S. Steel Corp. Mr. Hunter, in his talk, *Economic Optimism*, advised that we must "stop selling ourselves short." He recalled that Russia's first sputnik induced many to regard the United States as having been reduced to a second-class power. But he reminded his audience that, "Today there are 16 satellites in the sky. We put 15 of them into orbit. Outer space survivors include our first effort, Vanguard I, which was brushed off in some quarters as a grapefruit. Our satellites have photographed the earth's cloud cover, charted radiation belts, researched the weather, measured the earth's magnetic field, whirled out on a vast orbit beyond the sun, and sent back valuable data from 24 million miles in space."

Quo vadis electric furnace?

Closing the technical sessions of the Eighteenth Annual Electric Furnace Conference was a discussion of *Future Possibilities in Melting* with J. F. Elliott of MIT, N. H. Keyser of Battelle, and P. R. Gouwens of Armour Research dangling dynamic development possibilities before an overflow audience.

Professor Elliott led off by eulogizing the electric furnace as a clean, high-temperature heat source, but he emphasized the need to improve the heat transport process in order to provide greater furnace throughput. Suggested was the exploitation of the plasma jet as a higher-temperature heat source, but problems, such as the utilization of inert gases in the furnace and the economic conversion of electric energy to heat in the metal have hindered development along this line. He proposed that greater emphasis be placed on the use of special slags, broader use of vacuum techniques to remove volatiles, development of higher-temperature heat sources, charging of preheated scrap, and means of increasing heat transport by a mixing action in the bath similar to that of the LD process.

N. H. Keyser suggested the more extensive use of electronic controls in order to make electric steelmaking as automatic as possible. The computer should become the *melter*. Along similar lines, P. R. Gouwens pointed out that the real challenge was to learn more of the process in order to make melting variables predictable in such a fashion as to be able to set up computer control. Later discussion highlighted the fact that sufficient data was simply not available for computer control. However, at least one firm is actively collecting the required data by the use of a tape recorder whereon the melter describes each act that he performs during the melting operation with the reasons given for each decision and such data as temperature and analyses simultaneously recorded. Data from the tape is transcribed by a secretary into volumnous records which are to be kept over a considerable period and then studied for possible application to computer control.

Mr. Gouwens, at another point in his talk, emphasized the cost advantages possible in the utilization of auxiliary sources of lower-cost heat in the electric furnace. Moving a step further, he felt that it might be desirable to break up the steelmaking processes and use different furnace units for melt down and refining (see JOURNAL OF METALS, Aug. 1959 pp. 515-517). A duplex or triplex operation with furnace atmospheres controlled to optimize reactions at each stage of the process and the utilization of different refractories in each furnace might be a step forward. These ideas are along the lines of those expressed for some years now by Professor Elliott.

Mr. Gouwens also emphasized that the mixing problem should be pursued with the introduction of stirring action into various stages of the process, perhaps something along the lines of the *mixing ladle* (JOURNAL OF METALS, Jan. 1960, pp. 44-48).

With these very stimulating glimpses into future possibilities of electric steelmaking a most rewarding two days of technical meetings closed. Most would certainly agree that the future of electric steelmaking is bright! FWS

THE SENIOR CLASS:

Metallurgy and Metallurgical Engineering

by John P. Nielsen

This is the third year of the JOURNAL OF METALS' publication of the names of seniors in metallurgy and metallurgical engineering in the United States. The totals of such seniors in the last three years are as follows: 752 in 1959, 696 in 1960, and 751 in 1961.

The number of schools furnishing the 1961 total is 50. No list was received from one school that reported a total of 16 seniors last year, and presumably a similar total would have been reported this year had the list been received. In addition, two other schools reported that the metallurgy degree is no longer offered.

JOHN P. NIELSEN is professor and chairman, Dept. of Metallurgical Engineering, New York University. Data for this article were obtained under the auspices of the AIME Student Affairs Committee, John C. Calhoun, Jr. (Chairman), John R. Van Pelt, Jr., and John P. Nielsen.

The listing below includes only those specializing in extractive metallurgy, metallurgical engineering, materials engineering (or science), physical metallurgy, metal science, and metal physics. It *excludes* mining and mineral beneficiation engineers, geologists, ceramic and plastics engineers.

Lest there be any confusion, it should be noted that the listing below covers the seniors from the various schools as of December, 1960, and will not necessarily correspond to the list of actual graduates for this school year. In a number of cases the potential graduates of February and June are listed separately.

One special observation might be ventured. A third school has now adopted "materials" in its departmental title. One or two other schools known to the writer are contemplating such a change, and this might be an indication of a trend.

(Bold face indicates AIME member.)

UNIVERSITY OF ALASKA, College, Alaska, School of Mines, Donald J. Cook, Acting Head, Dept. of Mining and Metallurgy Seniors: R. Pray, B. Varnell.

UNIVERSITY OF ARIZONA, Tucson, Ariz., College of Mines, Dept. of Mining and Metallurgical Engineering, Prof. T. M. Morris, Head. Seniors: J. D. Beck, L. R. Branin, F. W. Cheesman, **W. A. Dawson,** L. P. Dvorak, **J. S. Erickson,** M. A. Khorouzan, **M. J. Monsegur,** R. C. Postels L. R. Williams, Jr.

POLYTECHNIC INSTITUTE OF BROOKLYN, New York, N. Y., Dept. of Mechanical Engineering, Prof. Charles T. Oergel, Head. Seniors: **J. Aliotta, P. Brady,** J. Conti, **E. Corrado, R. Cremin, J. Erickson,** R. Vill, **R. Guenther,** P. Gurian, **J. Hirschhorn, D. Leickhardt, E. Lieberman, L. Lozano, R. Maciag, E. McNicholas,** J. Niederman, **D. Newman, K. Niebling, M. Scolnick, M. Snyderman, P. Weinstein.**

UNIVERSITY OF CALIFORNIA, Berkeley, Calif., Dept. of Mineral Technology, Prof. Joseph A. Pask, Chm. Seniors: Bird, Warren M., Bonesteel, R. M., Dickson, C. M., Erickson, LaVerne C., Finnila, R. M., Johnson, E. B., Laubsch, E. P., Mitchell, J. B., Morris, W. G., Nason, Donald O., Onoda, G. Y., **Reams, E. J., Sullivan, D. A., Jr.**

CARNEGIE INSTITUTE OF TECHNOLOGY, Pittsburgh, Dept. of Metallurgical Engineering, Prof. C. L. McCabe, Head. Seniors: C. D. Green, **R. N. Brosius, I. L. Broudy,** G. H. Clark, **D. L. Creazzi, L. A. Dominik,** M. J. Dougherty, R. R. Fessler, **S. C. Fryncko, M. A. Georgelis,** R. C. Haverstraw, **D. D. Heiry, M. J. Hendrickson,** R. T. King, R. W. Landgraf, **P. J. Levine, D. R. McIlwain,** V. P. Panella, **S. L. Patel,** C. A. Queener, **R. Saul,** W. A. Soffa, **R. L. Stiehl, H. R. Tkatch.**

CASE INSTITUTE OF TECHNOLOGY, Cleveland, Ohio, Dept. of Metallurgical Engineering, Professor Alexander R. Troiano, Chm. Seniors: J. A. Bako, T. J. Black, J. A. Burnett, L. F. Draper, R. M. Dunco, J. J. Galdun, G. L. Hanna, D. E. Harris, D. C. Harsch, A. A. Hesse, J. C. Hosier, G. J. Hrastar, A. C. Lingenfelter, A. L. Mager, I. A. Newton, T. D. Nielsen, P. L. Raffo, **P. E. Repas,** J. L. Shohet, J. P. Siml, R. T. Soond, W. F. Stuhrke, **J. A. Vargo,** R. J. Votypka, C. I. Weiner, G. D. Willette.

UNIVERSITY OF CINCINNATI, Cincinnati, Ohio, Dept. of Chemical and Metallurgical Engineering, Prof. William Licht, Head. Seniors: E. Atkinson, Jr., J. H. Bucher, L. I. Edwards, C. D. Findley, R. Gall, G. A. Gronceski, J. P. Hunt, J. L. Kenty, D. M. Motter, J. E. Ramsey, J. R. Rosebrough, W. H. Roth, R. C. Schwab, R. M. Shemenski, G. K. Watson, D. L. Woods.

COLORADO SCHOOL OF MINES, Golden, Colo., Dept. of Metallurgical Engineering, Prof. H. Gordon Poole, Head. Seniors: P. R. Anderson, W. R. Andrews, **P. S. Arrieche,** G R. Beranek, **A. T. Biddle,** M. D. Brightwell, O. F. Carrington, H. P. Christiansen, J. D. Clark, L. E. Clay, **W. A. Cline, F. D. Coffman.** D. M. Dougherty, R. E. Dugger, **G. R. Edwards,** B. P. Faulkner, **J. E. Fuller,** E. E. Griffee, J. E. Gust Jr., **D. N. Halbe,** C. G. Hammerberg,

D. R. Harbur, G. E. Hasse, J. D. Henderson, B. B. Henry, J. J. Inouye, R. B. Kahler, **R. Kirchner,** A. Mayadas, M. J. McMahon, J. P. Meyer, A. W. Mooring, **R. E. Naumes,** D. H. Osborn, H. C. Osborne, **J. G. Pace,** J. M. Partridge. F. M. Patete, P. E. Phillips, R. A. Prescott, **W. G. Reuter,** P. W. Rice, J. D. Schieltz, R. L. Seal, W. N. Seery, D. R. Shearer, D. L. Siebert, T. C. Spangler, J. L. Sullivan, F. A. Thebus, **L. D. Webster, H. K. White,** W. P. Whitney, Jr., G. O. Zahn.

COLUMBIA UNIVERSITY, New York, N. Y., Dept., of Mining, Metallurgical and Mineral Engineering, Prof. M. D. Hassialis, Chm. Seniors: L. P. Connor, **R. H. Ericksen,** M. Gell, F. E. Helfrick, P. Skulte.

CORNELL UNIVERSITY, Ithaca, N. Y., School of Chemical and Metallurgical Engineering, Prof. C. C. Winding, Dir. Seniors: **P. C. Becker,** D. H. Haman, G. W. Kuhlman, Jr., J. T. Smith.

UNIVERSITY OF IDAHO, Moscow, Idaho, College of Mines, Dept. of Mining and Metallurgy, Prof. Joseph Newton, Head. Seniors: J. A. Cornie, **D. R. Evans,** D. W. McClanahan, J. J. Wick, Jr.

UNIVERSITY OF ILLINOIS, Urbana, Ill., Dept., of Mining and Metallurgical Engineering, Prof. Thomas A. Reed, Head. Seniors: **R. B. Anderson,** J. A. Astorian, W. Bottomley, R. V. Bradle, W. T. Collins, **T. R. Drews,** G. W. Duray, J. D. Ewing, **M. Garza,** G. A. Gegel, E. W. Godt, **G. R. Goetsch,** J. E. Higgins, H. R. Korte, F. L. Krempski, H. A. Levin, R. Lingwall, **R. J. Lotter,** W. Mossner, **F. Mueller,** D. L. Stoltz, **G. Vytanovych, R. Waterstrat,** J. G. Yadron.

ILLINOIS INSTITUTE OF TECHNOLOGY, Chicago, Ill., Dept. of Metallurgical Engineering, Prof. L. F. Modolfo, Chm. Seniors: J. T. Bates, J. C. Benedyk, **P. Borra,** K. J. Chudik, A. J. Cienkus, R. A. Cornog, **D. J. DeBall,** D. A. Duszak, G. S. Geren, F. S. Gezella, A. Gothelf, C. R. Klarich, R. D. Kraft, T. E. Lewis, **R. W. Lobenhofer,** D. G. Naranjo, **J. B. Schneider.**

UNIVERSITY OF KANSAS, Lawrence, Kan., Dept. of Mining and Metallurgical Engineering, Prof. K. E. Rose, Chm. Seniors: M. E. Bukaty, F. G. Hodge, K. O. McDowell.

UNIVERSITY OF KENTUCKY, Lexington, Ky., College of Engineering, Dept. of Mining and Metallurgical Engineering, Professor Richard S. Mateer, Head. Seniors (February) S. R. Kegley, R. M. Mabry, L. J. Nedosik. (June) J. C. Fister, Jr., J. A. Threlkeld.

LAFAYETTE COLLEGE, Easton, Pa., Dept. of Metallurgical Engineering, Prof. Leon J. McGeady, Head. Seniors: Bailine, F. G., Butler, J. M., **Crewdson, R. C.,** Davis, L. A., Dobay, K. J., Eitman, D. A., Grabarits, J. J., Hulsizer, W. R., MacDonald, D. F., McCain, B., Jr., Sedovy, J., Simpson, N. H., Wolf, R. C.

LEHIGH UNIVERSITY, Bethlehem, Pa., Dept. of Metallurgical Engineering, Prof. Joseph F. Libsch, Head. Seniors: (February) J. G. Gensure, L. R. Girke, (June) R. R. Campbell, **J. K. Chrisman, R. A. DePaul,** D. T. Dickson, R. W. Gallup, V. R. Goldthwaite, B. B. Holmes, J. H. Houston, Jr., R. G. Jackson, F. W. Liener, C. Meitzner, B. G. Parker, T. W. Rees, **F. A. Reilly,** D. L. Ritter, A. R. Roede, C. R. Roper, Jr., S. Siuciak, F. R. Varrese, C. B. Weidner, W. H. Welsch, J. C. Williams.

UNIVERSITY OF MARYLAND, College Park, Md., College of Engineering, Metallurgy Program, Prof. William A. Pennington, Head. Seniors: D. Betty, F. G. J. Boyer, R. L. Grudziecki, K. Kishinchand, B. J. Simmons, D. A. Witmer.

UNIVERSITY OF MASSACHUSETTS, Amherst, Mass., Materials and Metallurgical Engineering, Prof. Carl A. Keyser, in charge. (Senior thesis in metallurgy, degree designation in another field.) Seniors: D. J. Mraz.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY, Cambridge, Mass., Dept. of Metallurgy, Prof. John Chipman, Head. Seniors: (February) **J. Goldstein,** M. A. Moreno. (June) F. J. Bachner, B. P. Bardes, J. S. Benjamin, H. S. Berman, R. G. Blossey, R. D. Born, H. D. Cuklanz, D. R. DuBois, R. J. Dulsky, G. P. Gillum, L. Godfrey, H. H. Grieves, Jr., R. N. Katz, J. M. Kaufman, P. F. Lindquist, **B. Mravic,** R. S. Mroczkowski, H. R. Nesor, C. G. Robbins, **L. D. Schmer,** D. M. Schuster, T. Stefansky, C. S. Tedman, Jr., P. C. Veyron, W. J. Wagner, M. S. Walker, P. E. Yaffe.

UNIVERSITY OF MICHIGAN, Ann Arbor, Mich., Dept. of Chemical and Metallurgical Engineering, Prof. Donald L. Katz, Chm. Seniors: J. W. Abar, R. G. Allen, B. L. Beach, W. Boorstein, W. J. Gerus, G. N. Goldberg, K. J. Guion, J. F. Joseph, **J. C. Judd, R. G. Lang,** E. A. Merriman, **R. J. Parizek,** J. R. Pavlik, A. C. Walters, R. A. Westin.

MICHIGAN COLLEGE OF MINING AND TECHNOLOGY, Houghton, Mich., Dept. of Metallurgical Engineering, Dr. R. L. Smith, Head. Seniors: **M. A. Anderson,** F. R. Appleton, L. H. Blake, D. J. Borich, R. W. Brodie, **J. W. Butwell,** W. G. Carmody, C. J. Cattarello, L. M. Dahlin, D. G. Engquist, J. W. Erickson, D. N. Gibson, R. G. Grates, D. M. Hermanson, H. F. Jacobson, R. C. Johnson, D. S. Kopec, J. F. Kutey, W. J. Locher, W. W. Maki, R. L. Merklin, R. S. Michalak, D. M. Moon, L. O. Newton, R. M. Niemi, J. D. Opie, M. J. Puro, K. B. Rundman, J. W. Seeburger, R. A. Sega, E. T. Sheehan, R. R. Urich, D. F. VanDyke, D. A. Wick, L. S. Willet, C. H. Zatsick.

MICHIGAN STATE UNIVERSITY, E. Lansing, Mich., Dept. of Metallurgical Engineering, Prof. A. J. Smith, Chm. Seniors: D. H. Anderson, A. K. Bordine, R. A. Brocci, G. E. Edison, L. R. Griffiths, F. F. Heatley, J. Hrinevich, Jr., R. A. Karpinski, C. Korpak, G. D. Lawrence, D. I. Morton, W. E. Snow, D. E. Stellrecht, M. R. Vaughen, L. E. Willertz, W. B. Young.

UNIVERSITY OF MINNESOTA, Minneapolis, Minn., Dept. of Metallurgical Engineering, Prof. Strathmore, R. B. Cooke, Head. Seniors: R. H. Anderson, J. L. Bidler, R. Kielty, B. W. Mannila, **D. B. Nord, H. G. Posthuma,** L. Stefan, P. Winter.

MISSOURI SCHOOL OF MINES AND METALLURGY, Rolla, Mo., Dept. of Metallurgical Engineering, Prof. A. W. Schlechten, Chm. Seniors: (January) W. Amidei, Jr., R. H. Brockelman, C. L. Dohogne, M. L. Fulcher, **J. C. Gates,** S. Glucksman, W. A. Henning, J. T. Hughes, **K. E. King,** C. Parkash, **R. R. Pfeuffer,** R. H. Redline, R. P. Skow, J. D. Spagnola, P. G. Stern, F. W. Thielsen, (June) D. J. Albers, J. N. Baysden, R. L. Benner, G. D. Blevins, R. A. Booth, K. L. Brown, **J. E. Catron,** K. S. Chopra, T. W. Cook, L. L. Dix, E. V. Eppinger, J. R. Fish, **D. E. Furnish,** E. R. Gardner, G. K. Grechus, **N. M. Griesenauer,** G. S. Hall, J. O. Hunze, J. S. Jatem, **J. P. Kadlec,** S. E. A. Kessler, T. B. Lampe, J. M. Larkin, R. J. Litzler, F. E. Loftin, J. R. Long, W. H. McCluskey, **R. M. Merryfield, T. L. Mills, J. R. Ogle,** S. C. Owens, R. H. Redline, C. M. Roberson, **L. G. Roberts, R. M. Rose,** J. Romani, H. O. Schneider, B. C. Schwartz, R. Shah, A. Sousa-Poza, E. H. Stewart, G. E. Stigall, J. A. Straatmann, T. N. Turner, L. G. Twidwell, **W. E. Wistehuff, R. P. Zerwekh.**

MONTANA SCHOOL OF MINES, Butte, Mont., Dept. of Metallurgy, Prof. Vernon Griffiths, Head. Seniors: **D. E. Mahagian, D. J. McMillan.**

UNIVERSITY OF NEVADA, Reno, Nev., Mackay School of Mines, Dept. of Metallurgy, Prof. J. S. Winston, Chm. Seniors: **R. W. Neuschaefer, R. Turner, K. Uchida,** C. B. York.

NEW MEXICO INSTITUTE OF MINING AND TECHNOLOGY, Socorro, N. M., Dept. of Mining and Metallurgy, Prof. Frank W. Bowdish, Head. Seniors: (February) **J. J. Pulaski, Jr.**, (June) J. N. Brooke.

NEW YORK UNIVERSITY, New York, N. Y., Dept. of Metallurgical Engineering, Prof. J. P. Nielsen, Chm. Seniors: A. Benenfeld, **B. Bayles,** J. Fort, R. A. Hoffman, J. M. Papazian, **A. H. Reinstein,** R. Tauber.

NORTHWESTERN UNIVERSITY, Evanston, Ill., Dept. of Materials Science (formerly Metallurgy), Prof. Donald H. Whitmore, Chm. Seniors: Gosnell, J. R.

UNIVERSITY OF NOTRE DAME, South Bend, Ind., Dept. of Metallurgical Engineering, Prof. E. A. Peretti, Head. Seniors: (February) C. A. Macmillan, (June) J. W. Bette, A. M. DeBlasi, E. W. Gieselman, D. L. Jacobson, T. C. Jordan, G. T. Looby, D. F. Materna, J. F. Reilly, P. J. Rettig, J. D. Schiffgens.

OHIO STATE UNIVERSITY, Columbus, Ohio, Dept. of Metallurgical Engineering, Prof. Mars G. Fontana, Chm. Seniors: (Mrs.) Ferne L. Allan, J. L. Bomback, G. A. Busch, **R. E. Eppich,** T. J. Farrow, R. L. Kennard, S. E. Laub, D. W. Rausch, W. J. Sivakoff, D. K. Telle, R. E. Williamson.

THE UNIVERSITY OF OKLAHOMA, Norman, Okla., School of Metallurgical Engineering, Assoc. Prof. W. R. Upthegrove, Chm. Seniors: (February,) S. E. Conner, T. Lambrecht. (June,) S. E. Klein, J. R. McMahan, J. J. Slavick, B. D. Wagner.

UNIVERSITY OF PENNSYLVANIA, Philadelphia, Pa., School of Metallurgical Engineering, Prof. Robert Maddin, Dir. Seniors: R. H. Deitch, T. R. Drake, M. H. Glantz, C. E. Neu.

THE PENNSYLVANIA STATE UNIVERSITY, University Park, Pa., College of Mineral Industries, Dept. of Metallurgy, Prof. Robert W. Lindsay, Head. Seniors: G. F. Altemus, R. D. Ashe, W. E. Booker, J. N. Fleck, B. A. Fosnocht, R. A. Hampton, **S. G. Johnson,** J. Kidda, **J. E. Kosin,** R. J. Lusky, G. P. Marino, K. W. Maute, G. W. Meyer, **G. R. Mumau,** L. A. Niemond, R. P. Pallini, O. S. Pride, G. P. Sabol, P. E. Shattuck, C. W. Sowers, P. J. Stauffer, J. A. Thomas.

UNIVERSITY OF PITTSBURGH, Pittsburgh, Pa., Dept. of Metallurgical Engineering, Prof. J. A. Berger, Chm. Seniors: (December 1960) F. J. Arabia, G. M. Ecer, J. Petrolo, L. Tolchinsky. (June 1961) T. A. Auten, R. J. Bayuzick, D. F. Betz, D. W. Blewitt, R. V. Buzzard, C. A. Calvano, C. E. Carlson, B. A. Dorazio, F. J. Escribens, E. A. Evancic, J. F. Foley, A. S. Freed, T. W. Hauser, H. E. Horner, E. E. Isea, J. R. Jerich, J. F. Joyce, A. Kalin, A. C. Kelse, D. C Lepiane, W R. O'Connor, B. I. Pletcher, E. A. Pretka, L. A. Pugliese, A. D. Reinhardt, E. E. Ritchie, D. T. Rubolino, H. A. Treser, J. M. Valley, R. Wilson.

PURDUE UNIVERSITY, Lafayette, Indiana, School of Metallurgical Engineering, Professor Reinhardt Schuhmann, Jr., Head. Seniors: **F. G. Arcella, P. S. Ayres, L. W. Bella, J. W. Chasteen,** R. A. Choulet, N. E. Davis, D. R. James, R. L. Klueh, **J. W. Lodenkamper,** D. B. Martin, **S. G. Miller, J. O. Nelson, J. K. Percheski,** R. L. Persky, **W. G. Scheck,** H. P. Sims, **C. T. Tarr,** D. R. Trubey, **L. C. Walters, J. E. Yaste,** R. P. Vale.

RENSSELAER POLYTECHNIC INSTITUTE, Troy, N. Y., Dept. of Metallurgical Engineering, Prof. Arthur A. Burr, Head. Seniors: B. C. Barr, E. L. Bok, J. J. Briem, **R. A. Busch,** R. M. Campbell, **N. L. Church,** E. J. Crowley, S J. Donachie, L. Eisenbud, F. L. Guimond, F. S. Hering, R. W. Hindman, L. A. Jackman, **D. E. Jensen, L. E. Kindlimann, E. Koch,** K. F. Krysiak, R. B. Leonard, L. Nigohosian, W. T. Parker, E. D. Segal, C. I. Sherman, **J. L. Solomon, D. J. Tillack,** D. D. Vitale, S. C. Wang.

SOUTH DAKOTA SCHOOL OF MINES AND TECHNOLOGY, Rapid City, S. D., Dept. of Metallurgy, Prof. Paul H. Anderson, Head. Seniors: **P. V. Avotins,** H. L. Blizzard, **C. L. Bowman,** G. E. Burrer, **G. A. Daughenbaugh, M. F. Lackey,** F. C. Maciejewski, L. H. Nelsen, **L. I. Sherwood.**

STANFORD UNIVERSITY, Stanford, Calif., Dept. of Materials Science Prof. O. Cutler Shepard, Head. Seniors: **C. R. Barrett,** C. R. Heiple, **K. R. Kinsman, L. E. Kuhlken,** M. D. Merz, H. J. Saxton, T. G. Stoebe, J. F. Tompkins, V. Vagliente, R. R. Zupp.

STEVENS INSTITUTE OF TECHNOLOGY, Hoboken, N. J., Dept. of Metallurgy, Prof. Alfred Bornemann, Chm. Seniors: F. Abella, J. Alberino, **W. Arndt, R. Busch,** J. Canning, F. Chappa, F. Clarke, T. Coates, F. Dietrich, K. Dunphy, J. Giesen, S. Harasts, R. Hills, F. Keller, W. Lambertin, S. Lattoz, E. McLoughlin, D. Madore, W. Martin, E. Ramm, T. Ryan, J. Stamm, W. Stevens, A. Tamboer, W. Teves, W. Ullrich, J. Weiss, W. Zegel.

UNIVERSITY OF TENNESSEE, Knoxville, Tenn., Dept. of Chemical and Metallurgical Engineering, Prof. E. E. Stansbury, In Charge of Metallurgical Engineering. Seniors: T. L. Arledge, T. T. Hitch, R. Qualls, D. D. Randolph, T. C. Smith, R. P. Tucker.

TEXAS WESTERN COLLEGE, El Paso, Tex., Dept. of Mining and Metallurgy, Prof. J. C. Rintelen, Jr., Chm. Seniors: **R. Aguayo, A. Coggan,** G. Gutierrez, C. Hornedo, G. E. Krick, A. Muller, H. Rede, G. Rodarte, **C. Verdes.**

UNIVERSITY OF UTAH, Salt Lake City, Utah, Dept. of Metallurgical Engineering, Prof. Milton E. Wadsworth, Head. Seniors: **R. J. Anderson,** J. Bird, P. Chase, P. A. Dallas, A. B. Hertel, **G. Jump,** C. Kester, D. Mikich, C. S. Olsen, **L. Pember,** A. Suarez.

VIRGINIA POLYTECHNIC INSTITUTE, Blacksburg, Va., Dept. of Metallurgical Engineering, Prof. John F. Eckel, Chm. Seniors: M. L. Cook, H. L. Harrell, Jr., W. H. Hartt III, W. D. Hensley, L. D. Jamison, W. B. Lisagor, W. S. Lovelace, J. A. Munford, R. W. Ogershok, W. W. Robinson, B. Schwartz, T. E. Skorupa, F. L. Sult, R. W. Walls, A. H. Watkins.

UNIVERSITY OF WASHINGTON, Seattle, Wash., School of Mineral Engineering, Metallurgical Engineering Div., Prof. Earl C. Roberts, Head. Seniors: (December 1960) E. Austin, **C. Engdahl,** B. Schwenck, W. K. Sennott. (June 1961) **R. P. Allen,** E. T. Ault, D. J. Bailey, L. R. Ceder, R. T. Coleman, W. Gallagher, W. H. King, P. M. Leslie, **D. H. Nyman,** P. E. Rugg, N. A. Speed, W. F. Spurr, A. E. Thomas, L. P. Tillman, J. M. Vchida.

WASHINGTON STATE UNIVERSITY, Pullman, Wash., College of Engineering and Mineral Technology, Dept. of Metallurgy, Prof. S. A. Duran, Chm. Seniors: R. G. Baggerly, B. C. Deardorff, E. R. Gilbert, **G. G. Granger,** C. A. Javorsky, J. L. Landon, **L. H. Long, Jr., A. J. Lovell,** M. D. Martin, D. L. Reinhardt, W. A. Watts, J. A. Williams.

WAYNE STATE UNIVERSITY, Detroit 2, Mich., Dept. of Chemical and Metallurgical Engineering, Prof. H. G. Donnelly, Head. Seniors: (January) B. F. Hall, Jr., **R. S. Kiwak,** J. C. McKenzie, D. A. Scoble, (June) C. D. Behy, **G. A. Creegar, R. P. Eckel,** J. B. Padden, L. A. Winquist.

UNIVERSITY OF WISCONSIN, Madison, Wis., Dept. of Mining and Metallurgy, Prof. P. C. Rosenthal, Chm. Seniors: (January) R. W. Freigang, G. E. Laurhammer, G. H. Lenner, R. R. Matarrese, R. C. Onan, Jr., T. A. Richter, J. P. Tralmer, G. P. Wozadlo; (June) **R. A. Burmeister,** D. A. Carlson, J. C. Holman, Harnath Kapoor, **M. C. Lawlor,** R. C. Sellers, J. B. Veldhuizen.

YALE UNIVERSITY, New Haven, Conn., Dept. of Metallurgy, Prof. W. D. Robertson, Chm. Seniors: **C. E. Hayes,** C. H. Larson.

REPORT OF THE AIME COMMITTEE ON INTER-ENGINEERING SOCIETY COOPERATION

Douglas Ragland

R. M. Mahoney

Will Mitchell, Jr., Chairman

The October issues* of the Journals of the three AIME Societies carried a brief resume of the historical development of various technical and professional organizations which in some immediate or remote way affect the individual member of AIME. This resume was presented by the Institute Committee on Inter-Engineering Society Cooperation.

Recently, several plans have evolved designed as a first step to provide a so-called "unity organization" for the entire engineering profession. Almost all of the plans involve Engineers' Joint Council, Engineers' Council for Professional Development, and National Society for Professional Engineers in some way or other. Hence our committee is presenting to our membership a resume of the recent activities of the two umbrella organizations and of NSPE. More detailed information on any of these organizations may be obtained from annual reports published by the organizations.

Following the resume of activities of the three organizations there is a brief analysis of some of the unresolved problems facing AIME so far as any practical participation in the much publicized functional plan is concerned. This plan was described in the previous report by the committee.

* *Steps Toward Engineering Unity*, JOURNAL OF METALS, October 1960, pp. 808-811.

** Use of the seals of the founder societies does not imply endorsement of the report.

Activities of ECPD

The activities of the Engineers' Council for Professional Development are carried out through the medium of national committees on Guidance, Education and Accreditation, Student Development, Development of Young Engineers, Recognition, Ethics, and Information. One or more of the Societies of AIME is represented on each of these committees. Activities of unusual significance include:

1. Guidance

With the appointment this year of chairmen for Alaska and Hawaii, the network of ECPD guidance committees now extends over all 50 states, the District of Columbia and Canada. It is within these committees that the effective work of guidance is accomplished through personal contact with students, counselors, teachers, and parents.

The guidance activity of the State committees was supported by the National Committee through a variety of programs. In providing this support, the committee followed the general policy that engineering should be presented as a good career for the qualified with no special emphasis placed on particular branches of engineering, particular schools of engineering, or particular employers of engineers.

Two mailings were made to the nation's 30,000 high schools. The first went in November to school superintendents and principals. It included the "After High School What?" folder, a letter of transmittal explaining the guidance program, and a form for requesting speakers and other counseling assistance from the State chairmen. In February, the counselors of these schools were sent a similar mailing the current lists of ECPD accredited curricula in engineering colleges and technical institutes. These mailings ensured that administrators in practically all public, private, and parochial high schools were informed regarding the ECPD guidance services available to them.

2. Education and Accreditation

Engineering education today is dynamic. The increasing emphasis on science, greater depth in engineering analysis, new approaches to synthesis and design, rapid growth in graduate study and in research, curricula in new technologies—all are evidence of the transition and evolution occurring in engineering education. Some current educational innovations

are bold, imaginative, and experimental. Other changes are more conservative and evolutionary in character. No curriculum is static and all curricula reflect in one way or another the implicit rising demands of our expanding technology. Enrollment trends in engineering, science, and mathematics also are having direct effect on curriculum planning and development in engineering. Increased importance of graduate study in engineering is prompting serious evaluation of the undergraduate curricula as preparation for advanced study. And, beyond this current position is the growing interest in the concept of "professional engineering education," in the sense of medical and legal education, taught in a professional school following basic education in science, mathematics, the liberal arts, and fundamental engineering science.

To all such changes ECPD must be responsive, sympathetic, and encouraging. The Education and Accreditation Committee in this evaluation of curricula has followed the general guide lines of the ASEE 1955 Report on Evaluation of Engineering Education which were subsequently endorsed in principle by ECPD. At the same time, the committee has recognized the fact that no static standards or criteria for engineering education should exist and that curricula should be matched against rising standards of professional accomplishment and objectives. Consequently, the committee working within the general framework of the published "Basis for Accrediting of Engineering Curricula" and the "Additional Criteria" expects to see each school effecting continuing improvement through self-evaluation of curricula and objectives.

Graduate work in engineering is increasing rapidly and with it come problems of concern to the Education and Accreditation Committee. Pressure for accreditation of graduate programs continues to mount. Soon the present policy of accrediting "first degrees," whether carrying the B.S. or M.S. designation in a specified curriculum, will be inadequate to meet the issues raised by schools, professional societies, and industrial sponsors of part-time graduate study programs. For the purpose of assessing the problem, and recommending policy for E. & A. Committee consideration, and later for approval and action by ECPD, an ad hoc study group was established consisting of present members of the E. & A. Committee or recent alumni.

Authorized by Council in 1958, the E. & A. Committee has had representatives of the societies comprising ECPD and including the three Societies of AIME attend its meetings as observers. The representatives are the several Education Committee chairmen or their designees. Comments of the observers have been helpful to the E. & A. Committee. In turn the reports which the observers return to their Societies on the policies, procedures and efforts of the E. & A. Committee are useful in improved understanding of the committee's work and problems. The observers necessarily maintain the same discretion and hold the same confidence concerning committee discussions and recommendations as binds the regular members of the committee.

3. **Student Development**

This committee is continuing work on a brochure for use by students in the early years of their engineering education. It is the feeling of the committee that the earliest possible start should be made with students in colleges of engineering toward inculcating in these students the ideals of professionalism and in dispelling to the maximum possible extent the "sophomorish" casual attitude which too frequently exists.

Obviously, the wording and presentation in such a brochure is critical. It is recognized that the "Professional Guide for Young Engineers" now published by ECPD, is excellent for students at the senior or postgraduate level, but is quite inappropriate for underclassmen.

The three Societies of AIME are taking an increasingly significant part in all the activities of ECPD. The Boards of Directors and the Education Committees of the three Societies as well as the Board and the Council of Education of AIME are giving more consideration to the selection and the appointment of representatives to serve on the ECPD committees.

Activities of EJC

The Engineers' Joint Council advises on and coordinates matters of mutual interest to its constituent societies; it represents its constituents when joint efforts seem desirable; and it administers activities authorized by a majority of the constituent societies.

A Board of Directors, made up of representatives of the constituent societies and in numbers proportional to their membership, manage the Council. EJC, being a federation, the financing is by dues paid by the member societies. Membership in EJC includes ten constituent societies. However, provision is made for non-voting memberships of national and regional engineering groups as national associates and regional associates. At the present time there are three national associates and eight regional associates. Membership classification, as well as voting privileges, depend upon the size of the individual society and the provision that the majority of the membership of the group be engineers. AIME along with the other four Founder Societies are constituent members of the EJC. AIME now has three members on the Board of Directors of the Council which now numbers 29. There is an Executive Committee, which meets between council meetings, on which AIME also has a representative.

The objectives of the Council are published in the constitution and are not detailed here. However, they include the promotion of cooperation among the various branches of engineering, and the development of recommendations regarding public service policies respecting national and international affairs in areas where the application of the art and science of engineering will contribute to the general welfare of mankind. The Council endeavors to secure more efficient utilization of the scientific and technical potentialities of the art and science of engineering and of engineers, so that they may better serve the welfare of the nation during times of peace and for the defense of the nation in time of war.

The objectives are implemented by such committees as Engineering Information Services, The Engineering Manpower Commission, Engineers' Research Committee, Information Processing Committee, International Relations Committee, Technical Planning Committee, National Transportation Policy Panel and National Water Policy Panel. During 1960 the Council instituted a quarterly publication, the "Engineer", so that the objectives and activities of the Council could be portrayed in more detail than had been previously possible. Each member of AIME receives a copy of "Engineer".

During the year EJC has participated with ECPD in an effort to provide a broad "survey of the engineering profession. It has established a liaison with the Engineering and Industrial Research Division of the National Research Council of the National Academy of Sciences. It has continued its study with the American Institute of Architects on inter-relationships of architects and engineers, and acted as a coordinator of the April 1960 Nuclear Congress. It is cooperating with the Engineering Foundation in considering the possibility of establishing a national academy of engineers and it participates in the activities of the American Association for the Advancement of Science, and maintains official participation with the United Nations Educational, Scientific and Cultural organization.

Activities of NSPE

NSPE dedicates itself to the promotion of the profession of engineer-

ing as a social, ethical and economic influence vital to the affairs of men and the United States. Its objectives are accomplished through the society's programs on local chapter, state society, and national levels. The Society holds that every engineer has two total areas of interest, one technical and one professional, the professional interests being common to all engineers rather than to the interest of any sectional group. One objective of the Society is to offer a vehicle to stimulate engineering leadership in public service activities. Another is to provide the opportunity to assist young engineers in meeting professional problems. The Society aims to establish standards of professional conduct for the protection of the public and the profession and offers the opportunity for personal participation of the engineer in a comprehensive program for the advancement of professional ideals and concepts.

The membership in NSPE is made up solely of engineers registered in any one, or several, of the States. The national organization is governed by a Board of Directors made up of representatives from each of the 50 states in proportion to the number of registered engineers in the given state. The objectives of NSPE are implemented by national committees such as Employment Practices, Engineers in Industry, Ethical Practices, a Functional Section for Engineers in Government Practice, Functional Section of Consulting Engineers in Private Practice, Functional Section for Engineers in the Armed Services. NSPE has an Inter-Society Relations Committee, a Committee of Engineering Technicians and on Engineering Preparation, as well as several other committees concerned with the administration of such an organization as it is. The Society recommends that each of its members join and support the work of the technical society which serves his particular field of practice and, according to a recent survey made of the membership, three out of four members of NSPE are members of one or more of the technical societies with more than half of them being members of the Founder Societies.

NSPE maintains committees and paid staffs at national and state levels. Among other activities it watches closely all proposed legislation in which engineers are interested; it publishes information concerning these legislatives matters to its members and it makes its views known to the appropriate committees in Congress and in the state legislatures.

AIME and the Functional Plan

Very briefly stated, in the functional plan as suggested by the AIEE the many technical educational and professional activities of the engineering profession would be the responsibility of EJC, ECPD and NSPE. EJC would coordinate the universal technical activities of the the technical societies; ECPD would coordinate the educational activities for the profession and the NSPE would have the responsibility of coordinating the professional aspects including legislative matters that affect the profession.

As reported previously, AIME is a constituent society of EJC and ECPD and accepts its share of the financial responsibilities of the operation; whereas NSPE is made up of individual dues paying members. AIME as an Institute could not be a member of NSPE and members of AIME can belong to NSPE only by applying for membership in this completely separate and independent organization which requires that applicants be registered as professional engineers in one or more states. From a most recent estimate, approximately only 1500 AIME members out of a total of our 36,000, are members of NSPE.

It is obvious that EJC and ECPD adequately represent AIME in their areas of operation, however it is also obvious that NSPE is not in a position at the present time to represent AIME in one important segment of the functional plan. It is realized that there may be many AIME members who are registered engineers in the various states who are not members of the National Society of Professional Engineers. However, by no reasonable extrapolation can NSPE today be considered as representing the professional interests of our metallurgical, geological, mining and petroleum engineers. The committee realizes there are many valid reasons why more of our members have not become members of NSPE. As stated previously, NSPE requires that all of its members be registered engineers in at least one of the 50 states. However, we realize in past years that legislation on registration of engineers was often written into the laws of the various states through the efforts of consulting engineers in the field of civil engineering. Naturally the examinations that were set up in these states were oriented to the discipline of civil engineering. More recently, mechanical engineers and electrical engineers have prevailed upon the State registration boards to establish examinations suitable for their respective disciplines. At the present time, there are many states that do not have examinations suitable to the training of the engineers in the mining, metallurgical and petroleum industry. The same situation holds for the chemical engineering discipline, sanitary engineering, radio engineering, etc. In fact, the laws have not kept pace with the advance of technology, making no provision, to cite examples, for fields involving earth structures important in dam and tunnel construction, radioactive waste disposal, smog control, and other problems of smoke abatement. All of these are directly in the field of public health and welfare.

Because of the nature of our profession in the mineral industry, the members of AIME in general are professional salaried employes on the technical and management staffs in mining, metallurgical and petroleum corporations. A relatively small proportion of our people are in consulting practice. However, those so engaged are concerned in the requirements of registration very keenly and many are handicapped by the difficulty of becoming registered in their fields of competence. It is for the benefit of those members who now or in the future may be so engaged in consulting work involving public health and welfare that AIME should concern itself with the problems of licensing and registration and with the examinations which our members must take to qualify.

At a recent AIME board meeting, President Gillson and the committee were authorized to make a survey of the 50 states in order to determine in which states our members could or could not be registered. In a preliminary analysis, the committee found that there are 14 states in which AIME has representatives on state registration boards of professional engineers. It is presumed that in most of these states suitable examinations should be available for our people. In the meantime, representatives of the National Council of State Boards of Engineering Examiners have offered to cooperate with AIME in its efforts, and the NSPE Board of Directors at their last meeting in Denver voted to cooperate with AIME in attempting to establish suitable examinations for AIME members in those states where such examinations do not exist.

Until this survey is completed, the AIME committee on Inter-Engineering Society Cooperation feels that it is not in a position to make any recommendations on this particular subject.

It has been encouraging to the committee to note that several of the larger technical societies have joined in suggesting to NSPE that the membership requirements of the National Society be relaxed to permit the acceptance of engineers of eminence and experience into NSPE without examination for a reasonable period of time. Should NSPE open its membership to engineers of eminence and experience regardless of whether they are registered professional engineers, then a substantial number of members of AIME may join NSPE and help guide the activities of that organization in professional fields so that it then can be of service to engineers in mining, metallurgical, and petroleum engineering.

100th Anniversary— Verein Deutscher Eisenhuttenleute

The Verein Deutscher Eisenhuttenleute celebrated its 100th anniversary on November 3-4, in Dusseldorf, Germany. A special program was planned for the members and foreign visitors. The meeting was attended by West German Chancellor, Konrad Adenauer.

William O. Binder, metallurgical consultant of Union Carbide Development Co., represented the Iron and Steel Division of The Metallurgical Society at the meeting. AIME was represented by Howard Biers of the Market Research and Development dept. of Union Carbide International Co.

The Verein Deutscher Eisenhuttenleute (VDEh) was founded at a time when production of the Rhineland-Westphalia industry comprised mainly charcoal iron and puddled iron, steelmaking by the open hearth and bessemer processes having just begun. Production of charcoal iron ceased in 1870, while puddled iron production, which reached a peak of nearly a million tons in 1880, continued on a decreasing scale until 1930. The open hearth and basic bessemer steelmaking processes have made steady progress, but are now beginning to give way to oxygen steelmaking methods, which, it is expected, will soon be responsible for as much as one-fifth of West Germany's steel output.

Development of the steelmaking processes was reviewed by F. A. Springorun, of Mannesmann AG, who showed how the local trade of charcoal ironmaking in the river valleys was transformed into the enormous iron and steel industry of the Ruhr coal mining district, thanks to the introduction of the acid bessemer converter (1862), the siemens martin (or open hearth) furnace (1871), and finally the thomas converter (1879). The higher quality of the steel made in open-hearth furnaces brought this process into the leading place (60 pct) until World War II, when it was shown that the use of oxygen in the thomas converter could be a convenient way of achieving a low phosphorous and nitrogen content.

H. Kallen, of the Krupp Works in Essen, stressed the importance of research in the iron and steel industry. He outlined the progress made in steel analysis and testing techniques. The first research centers in Germany appeared at the turn of the century, and their initial task was to investigate the possibilities of alloying and of heat treatment. Today, fundamental research is centralized in the Max Planck Institut in Aachen, founded by the VDEh in 1917 as the Kaiser Wilhelm Institut für Eisenhuggenforshung, a part of the Kaiser Wilhelm Gesellschaft. A feature of steelmaking over the past 50 years has been the industry's ability to keep pace with the increasingly varied requirements of the steel-using industries by the development of suitable grades of steel.

The increasing importance of production costs in the face of keener competition in world markets was emphasized by P. Rheinlander of the Salzgitter Works. The effect of the rising level of wages in the extremely tight West German labor market has been balanced by the rising per capita production of the steelworker, which has doubled over the past 20 years, due mainly to mechanization and modernization of plant and equipment. Nevertheless, still higher productivity will be required before any further reduction in working hours can be given. Otherwise the present standard of living cannot possibly be maintained. Transport costs, both for raw materials and for finished products, also play an important part in setting iron and steel prices, so that in planning the construction of a new works, very special consideration has to be given to the location. Availability of cheap water transport continues to ensure a reasonably low level of transport cost in the Ruhr, but now a new factor has arisen in the form of a change in the traditional relationship between coal and oil prices, and its effect is already to be seen in the trend away from the coal mining districts towards the coast in the location of new works.

The development of the shaping and finishing end of the German iron and steel industry from the early steam-driven mills to the present was reviewed by W. Ochel of Hoesch AG, Dortmund. The world's first continuous sheet mill, Dr. Ochel pointed out, was not made in the United States, as is generally believed, but was designed and built by a German firm of plant makers as long ago as 1900. Technical difficulties, however prevented its general adoption, and in the end it was the American wide strip mill which revolutionized the manufacture of sheet in the main steelmaking countries of the world. Last year over half of West Germany's sheet production came from wide strip, and total output of the strip mills reached 2 million tons.

The VDEh chairman, H. Schenck, addressing the General Assembly on November 4, discussed several questions affecting the iron and steel industry. While emphasizing that a keen watch must be kept on the development of competitive materials, Dr. Schenck believes that their effect on the steel trade over the next decade will be limited. Competition by other steelmaking countries is quite another matter. Here, according to Dr. Schenck, the German industry is finding its hands tied more and more.

Steel expansion in Germany and other steel producing countries has been forging ahead, and also, many of the importing countries are increasing efforts to cover their own requirements and achieve an export surplus. It is probable that supply will increase faster than demand, and only those steelmakers able to offer products at the most favorable prices are likely to win through. All industrialized countries accept the principle of the economic advantage of the large industrial unit; but, according to Dr. Schenck, experience has shown that proposals along these lines by the steel industry, in the form of expansion or mergers, are regarded with suspicion. There is no longer any justification, Dr. Schenck said, for using the old bogey of trusts as an excuse for exercising control of investment in individual German firms.

The JOURNAL OF METALS is indebted to William O. Binder, the ISD representative at the VDEh meeting, and to the Intelligence Dept. of the British Iron & Steel Federation for providing this information.

AIME STAFF:
SECRETARY—ERNEST KIRKENDALL
ASST. SECRETARIES—J. B. ALFORD, H. N. APPLETON, J. C. FOX, S. W. SHEARMAN, C. J. NICKS
ASST. TREASURER—JOHN LYNCH
METALLURGICAL SOCIETY STAFF:
SECRETARY—S. W. SHEARMAN
ASST. SECRETARY—D. C. JOHNSTON

NEWS OF YOUR PROFESSION

SPEAKERS & TOPICS ARE ANNOUNCED FOR ANNUAL MEETING IN ST. LOUIS

The three divisions of The Metallurgical Society have announced speakers and topics for lectures and luncheons during the Annual Meeting in St. Louis, February 26-March 2.

Lawrence S. Darken will deliver the Iron and Steel Division's Howe Memorial Lecture on Tuesday, February 28, at 11 am in the Empire Room of the Ambassador Hotel. His subject will be *The Role of Chemistry in Metallurgical Research*. Dr. Darken, associate director of the Edgar C. Bain Laboratory for Fundamental Research in Monroeville, Pa., has been associated with U.S. Steel Corp since 1935. He has been engaged in research in many areas of both physical and chemical metallurgy—the common threads being most frequently thermodynamics and diffusion.

Following Dr. Darken's lecture, the Iron and Steel Division's Annual Luncheon will be held in the Ambassador's Caesar Room at 12:15 pm with J. J. Golden presiding. The speaker will be Lyle F. Gulley, vice president in charge of operations, Granite City Steel Co.

The All-Institute Session will meet at 2:30 pm in the Khorrassan C Room of the Chase Park-Plaza Hotel. The State of the Institute Address will be made by AIME President Joseph L. Gillson.

On Tuesday evening February 28, The Metallurgical Society will hold its Annual Dinner at the Ambassador Hotel. The affair will begin with a social hour in the Coronation Room at 6 pm. At 7 pm, the group will move to the Empire Room for dinner. Following the dinner, three awards will be presented with C. C. Long, President of The Metallurgical Society presiding. The **J. E. Johnson, Jr., Award** will be presented to R. J. Wilson; the **Champion H. Mathewson Gold Medal** to K. T. Aust and J. W. Rutter; and the **Robert W. Hunt Medal** to Y. Doi and K. Kasai. Featured speaker at the dinner will be Richard J. Anderson, assistant to the director, Battelle Memorial Institute. In his talk, *Journey into Ignorance*, Mr. Anderson will discuss in a serious, yet light manner, some of the interesting findings of the International Geophysical Year. Mr. Anderson, who was trained as a geologist, graduated from Columbia College in 1935 and received his master's degree from Columbia in 1938. He spent the next ten years in professional assignments both in this country and abroad. He conducted field investigations in the Union of South Africa, Alaska, and several of the western states. His professional experience includes a period of teaching at the University of Minnesota, a wartime appointment as State Geologist of Arkansas, and extensive exploration missions for Aluminum Co. of America. In 1948, he went to Battelle Memorial Institute, where he has served in various administrative posts.

The Institute of Metals Division Lecture will be presented Wednesday morning at 11 am in the Empire

(Continued on page 169)

J. B. Cohen Receives Robert Lansing Hardy Gold Medal Award

Jerome B. Cohen, assistant professor in the Dept. of Materials Science at Northwestern University, has received the AIME's Robert Lansing Hardy Gold Medal for 1960. Presentation was made January 4, at a meeting of the Chicago section. The Medal, first awarded in 1957, was established by Arthur C. Hardy of Massachusetts Institute of Technology, in memory of his son, who died in 1954 while a student at M.I.T.

The Medal is given to a person under 30 years of age who is nominated by the AIME local sections as showing the most promise in the field of metallurgy.

Dr. Cohen received his ScD from M.I.T. in 1957, and studied as a Fulbright Scholar at the University of Paris in 1957-58.

Management Session Is Scheduled For Annual Meeting

One of the features of the Annual Meeting to be held in St. Louis will be the Engineering Management Session which will be held in the Tiara Room of the Chase Park-Plaza Hotels on Wednesday, March 1, at 9 am. Chairman of the session will be Bruce S. Old of Arthur D. Little, Inc.

The papers to be presented are *Management of Innovation*, by Eldon Sweezy, of the Ordnance Corps, Dept. of the Army; *The Principles of Organization*, by J. Herbert Hollomon, General Electric Co., and *Conditions of Facility, Collaboration and Work*, by Prof. Herbert Shepard, Case Institute of Technology.

Third Symposium on Electron Beam Slated for March 23-24

Alloyd Electronics Corp. is continuing with its Third Annual Symposium on Electron Beam Technology. This year's symposium will take place in Boston March 23-24.

The symposium will consist of four sessions. The first two on the 23rd will involve *Electron Beam Physics;* and *Welding and Refining*. The second two sessions on the 24th will include *Applications of Electron Beams* for advanced techniques such as polymerization, food processing and other varied areas; and *Present and Future Applications of Electron Beams to Micro-electronics*.

Technical papers will be presented by leading scientists representing organizations working in these advanced areas of electron beam technology.

As in the past, the attendance will be limited so the greatest interchange of technical information will be possible. For detailed information, write to *R. Bakish, Chairman, Third Alloyd Symposium, 37 Cambridge Parkway, Cambridge 42, Mass.*

Corrosion Congress Scheduled in London April 10-15, 1961

The First International Congress on Metallic Corrosion will be held in London April 10-15. The meeting will be held at the Imperial College of Science and Technology. A feature of the meeting will be a lecture on Tuesday, April 11, on *Electrochemical Behavior of Metals on the Anodic and Chemical Passivation in Electrolytic Solutions*, by Prof. Y. Kolotyrkin (USSR). A works visit is scheduled for the same day.

Other papers to be presented include *Radiotracers as Applied to the Study of Metallic Corrosion; The Advancing Frontiers of Corrosion Science* by Professor H. H. Uhlig (USA), and *Factors Deciding Between Active Corrosion and Protective Film Formation.*

Proceedings of all sessions, including scientific papers, will be published after the conference by Butterworths, 88 Kingsway, London, W.C. 2.

Business Meeting

The regular Annual Business Meeting of the AIME will be held on Tuesday afternoon, February 28 at 4 p.m. in the Khorassan C Room of the Chase Hotel in St. Louis, Mo. The meeting will immediately follow the All-Institute Session at the Annual Meeting.

Four Field Trips Planned for March 2, During Annual Meeting

Four field trips have been scheduled for Thursday, March 2, during the Annual Meeting in St. Louis.

Mallinckrodt Chemical Co., at Weldon Springs, Mo., will be the site of one of the visits. Operations at this plant include the processing of uranium ores and reduction to metal. Price of the trip is $5.00 per person.

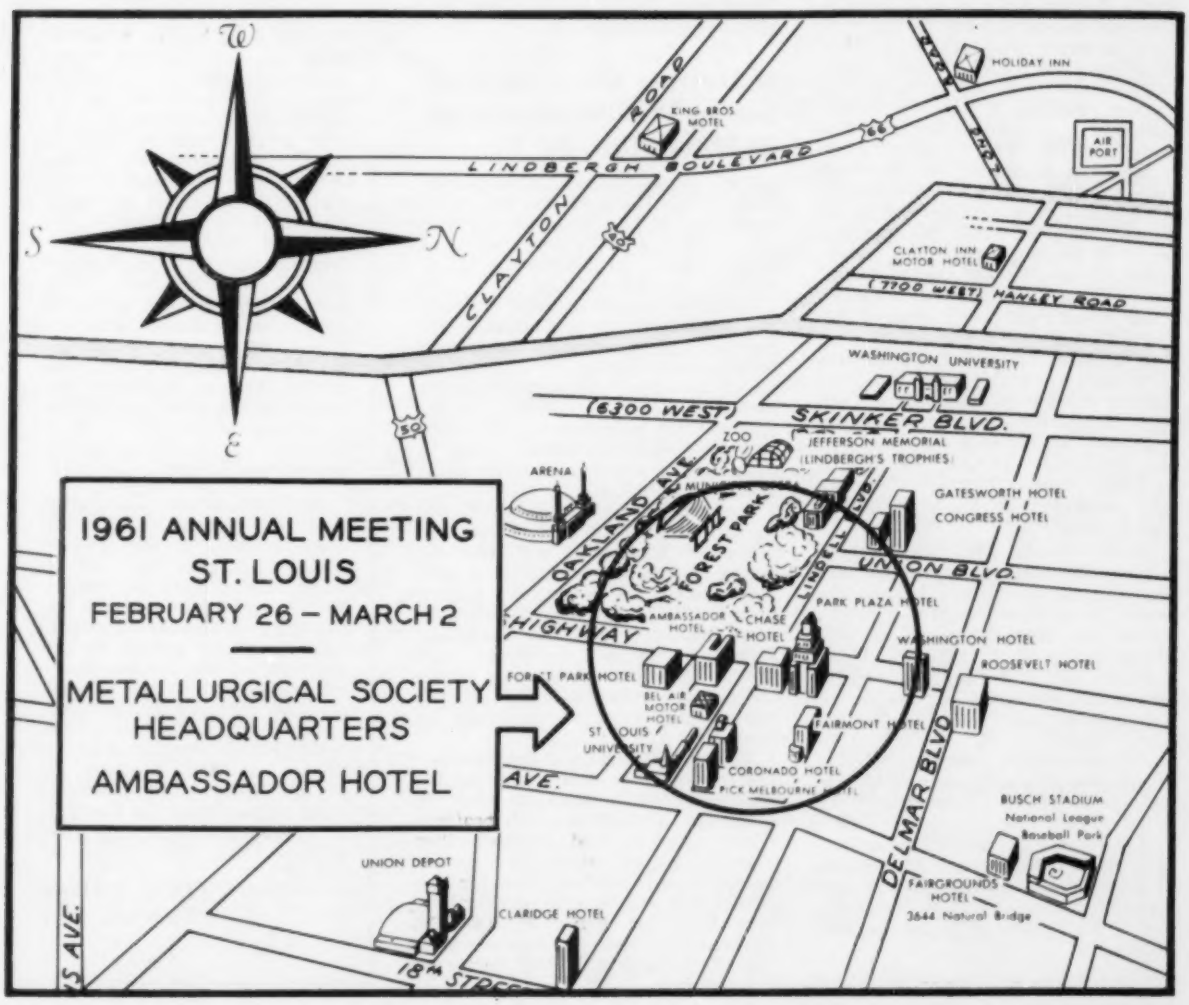
Another visit planned is the one to the Viburnum Mine of St. Joseph Lead Co. at Viburnum, Mo. A new ore body discovered in this area has resulted in the construction of a modern 3000 tpd mill. Tickets for this visit are $10.00 each.

Shell Oil Co.'s large integrated petroleum processing plant at Roxana, Ill., is another installation to be visited. Tickets are $4.00 each.

A visitor to the River King mine of Peabody Coal Co., at Freeburg, Ill., will have an opportunity to see *Big Paul*, a 70-yd bucket excavator, and a wheel excavator. Tickets for this visit are $4.00 each.

Transportation to all tour sites will be by bus departing from the Chase Park-Plaza Hotels.

Tickets for the trips may be purchased in advance by making remittance payable to *Henry Day, Treasurer, c/o AIME-, 29 West 39th St., New York 18, N. Y.* Tickets will also be on sale at the Meeting.



AIME To Participate in Metals Congress in Los Angeles

The Southern California section of AIME will participate in the Western Metals Exposition and Congress which will be held at the Pan Pacific Auditorium in Los Angeles, March 20-24. The Southern California section consists of two branches: the Metals Branch and the Minerals Branch.

The Metals Branch participated in the last two Metals Congresses in 1957 and 1959, and this year has organized four sessions to be held at the Ambassador Hotel.

The first session on **Materials at Their Highest Strength—Whiskers,** will be held on Tuesday afternoon, March 21. *Behavior of Whiskers at Elevated Temperatures and Their Possible Application in Composites* is the title of a paper to be delivered by S. S. Brenner of the General Electric Research Laboratory. **Paul J. Shlichta,** Jet Propulsion Laboratories will present a paper on *Size Effects in Ultra-Strength Materials,* and Bruce Daniel of the physics section, Midwest Research Institute has prepared a paper on *Strength of Al_2O_3 Whiskers Coated with Metallic Films.* Other papers will be presented by Helmut Weik of Wright Air Development div., and Roger Bacon of National Carbon Research Laboratory.

The second session on **Vacuum Thin Film Metallurgy** will be held on Wednesday morning, March 22. Gordon Steel of Servo Mechanisms Inc., will present a paper on *Metallurgy, Structure, and Application of Thin Films. Introduction Magnetic Thin Films* will be discussed by Floyd Humphrey of the Jet Propulsion Laboratory, and **Robert Sloan** of Sloan Research Industries will present a paper on *Analysis of Thin Film by Electron Microscopy, X-ray Diffraction and X-ray Spectroscopy.* The final paper at this session will be *Thin Films as Corrosion Indicators,* presented by David Roller of Magna Products.

On Wednesday afternoon the third session, **Refractory Alloys—Properties** will be presented. Among the papers to be presented are *Tantalum Alloys for High-Temperature Applications* by F. F. Schmidt, D. J. Maykuth, and H. R. Ogden of Battelle Memorial Institute; *Oxidation of Tungsten at Low Pressure and High Temperature* by R. A. Perkins of Lockheed Missile and Space div.; *Dispersion Strengthening of Molybdenum at High Temperatures* by W. V. Green and Thomas J. Ready of Los Alamos Scientific Laboratory; and *High-Temperature Mechanical Properties of Tungsten-Columbium-Tantalum Alloys* by C. R. McKinsey and J. L. Wilson of Union Carbide Metals Co.

(Continued on page 171)

Minerals Industry Conf. Meets April 24-25 in Las Vegas, Nev.

The Southwest Minerals Industry Conference will be held at the Stardust Hotel in Las Vegas, Nev., April 24-25. One of the features of the meeting will be an Extractive Metallurgy Session on Monday, April 24. There will be papers on *Steel Manufacture in the Pacific Southwest—The Market & Raw Material Potentials, Alumina from San Gabriel Anorthosite,* and *The Atlantic City Project.*

An All-Participants Luncheon will be held on Tuesday, April 25, and will feature a talk on *COMINCO* (Consolidated Mining & Smelting Co. of Canada Ltd.) by R. R. McNaughton, President of AIME.

On Tuesday afternoon, there will be a Physical Metallurgy Session which will offer a paper on *Casting of Tungsten Base Alloys* by Russell Hardy, chief metallurgist of Oregon Metallurgical Corp. Other papers include *Electron Beam Melting, Corrosion Resistant Applications of Titanium,* and *Improved Austenitic Manganese Steels for Abrasion Resistant Applications.*

Materials Management Group Will Meet in May at Harriman, N. Y.

The newly-formed Management of Materials Research and Engineering Group of The Metallurgical Society plans to hold its first meeting at Arden House in Harriman, N. Y. May 17-19, 1961.

Problems in management of materials research will be explored, appraised, and resolved utilizing four techniques: lectures by leading research managers, case history clinics, lectures on the principles of management by established authorities, and work shop-discussion groups to develop information on specific management problems.

The spring meeting will be directed toward two types of management personnel: established managers and young or prospective managers, with the intention of setting up a program of deriving research management principles. It is felt that established managers would be best served by seminar programs where individual problems could be discussed and experiences could be shared.

Some of the topics to be discussed are: organization and staffing of industrial research, management problems, appraisal of research projects, communication, and various other topics in fundamental scientific management. Registration fees for the conference will be $200 for members and $250 for non-members. The proceedings will be published in The Metallurgical Society Series by Interscience.

IMD BYLAW REVISION

All members are hereby notified that the following amendment to the Bylaws of the Institute of Metals Division of The Metallurgical Society of AIME was proposed at the meeting of the Executive Committee on October 18, 1960, and will be voted on at the annual Business Meeting of the Division to be held at 10:45 am on Wednesday, March 1, 1961, in the Empire Room of the Ambassador Hotel in St. Louis:

Article VIII, Section 8—The Lecture Committee shall consist of four members of the Division, one appointed each year for a term of four years by the Chairman of the IMD, subject to the approval of the Executive Committee. The member in his second year of service shall be Chairman of the Lecture Committee.

a) It shall be the responsibility of the Lecture Committee to select an outstanding scientific leader to present a lecture on a technical subject of particular interest to the Division at a meeting approximately two years following the time of his selection. The selection is subject to the approval of the Executive Committee, and the Division Secretary shall promptly thereafter report the action to the Programs Committee. The lecture-nominee shall be notified by written invitation prepared by the Division Secretary and signed by the President of The Metallurgical Society at least eighteen months prior to the date of the lecture.

b) The Lecture Committee shall be responsible for the arrangements of the lecture presented during its year of office. It also shall be responsible for the itinerary of the lecturer. Financial arrangements shall be subject to the approval of the Budget Committee. An appropriate citation shall be prepared by the Committee for presentation to the lecturer. The lecture shall be known as the Institute of Metals Lecture and the lecturer shall be known as the Institute of Metals Lecturer for that year.

D. C. Johnston
Secretary

Speakers Listed . . .

(Continued from page 166)

Room of the Ambassador Hotel. The speaker will be David Turnbull of the General Electric Research Laboratory, Schenectady, N. Y. His subject will be *The Liquid State and the Liquid-Solid Transition.* Mr. Turnbull received a Ph.D. in Physical Chemistry from Monmouth College in 1939. From 1939 through 1946 he was engaged in teaching and research at Case School of Applied Science. He joined the General Electric Research Laboratory in 1946, and since that time has contributed to the following fields; diffusion in solids and liquids; mechanism of phase transformations; recrystallization and grain growth in metals; and most recently, the liquid state and the glass transition. From 1950-58, Mr. Turnbull served as manager of the chemical metallurgy section of the G. E. Research Laboratory, and in 1957-58, he spent six months at Cambridge University on a leave. He is co-editor with Frederick Sietz of the *Solid State Physics Series* published by Academic Press.

The EMD Annual Stag Luncheon will be held Wednesday at 12:45 pm in the Caesar Room of the Ambassador. Featured speaker will be A. Carl Weber, director of research and engineering at Laclede Steel Co. A graduate of Washington University, Mr. Weber will speak on *Where Is Our Strength.*

Antoine M. Gaudin will deliver the Third Extractive Metallurgy Division Lecture on Thursday, March 2 at 11 am in the Empire Room of the Ambassador Hotel. The subject of his talk will be *Separation Engineering.* Dr. Gaudin is the Robert H. Richards Professor of Mineral Engineering at the Massachusetts Institute of Technology Professor Gaudin received a Bachelor of Science degree from the University of Paris in 1916, and graduated from Columbia University as an Engineer

(Continued on page 171)

Metallurgical Society Committee Meeting Schedule

1961 AIME Annual Meeting • Ambassador Hotel, St. Louis

Sunday, February 26

11:30 am	IMD Past Chairmen's Luncheon (Parlor 116-117)
12 m	Metallurgical Society Education Committee Meeting (Parlor 108)
4:30 pm	IMD Membership Committee Meeting (Parlor 145)
4:30 pm	IMD Programs Committee Meeting (Parlor 130)
6:00 pm	EMD Executive Committee Dinner (Parlor 116-117)

Monday, February 27

10:30 am	Committee on the Metallurgical Profession Meeting (Parlor 145)
12:15 pm	ASM Committee Luncheon (Parlor 116-117)
3:00 pm	IMD Refractory Metals Committee Meeting (Parlor 145)
4:00 pm	IMD Budget Committee Meeting (Parlor 108)
4:00 pm	IMD Publications Committee Meeting (Parlor 116-117)
4:00 pm	IMD Structural Materials Committee Meeting (Parlor 130)
5:00 pm	Metallurgical Society Membership Committee Meeting (Parlor 145)

Tuesday, February 28

8:45 am	Metallurgical Society Programs Committee Meeting (Parlor 108)
9:00 am	ASTM Committee B-2, Subcommittee VIII (Molybdenum) (Parlor 145)
12:15 pm	IMD Executive Committee Luncheon (Parlor 116-117)
12:15 pm	Yale Metallurgical Society Luncheon (Parlor 130)

(Continued on next column)

Tuesday, February 28, Continued

12:15 pm	IMD Chemistry & Physics of Metals Committee Luncheon (Parlor 144)
2:00 pm	ASTM Committee B-2, Subcommittee VIII (Tungsten Specifications) (Parlor 145)
2:00 pm	ISD Executive Committee Meeting (Parlor 108)
3:00 pm	IMD Semiconductors Committee Meeting (Parlor 130)
3:00 pm	IMD Melting & Casting Committee Meeting (Marquis Room)
4:00 pm	EMD Technical Committee Chairmen's Meeting (Versailles Room)
4:00 pm	IMD Nuclear Metallurgy Committee Meeting (Parlor 144)

Wednesday, March 1

7:30 am	Metallurgical Society Board of Directors Breakfast (Parlor 116-117)
9:00 am	IMD Corrosion Resistant Metals Committee Meeting (Parlor 108)
9:00 am	Journal of Metals Advisory Subcommittee Meeting (Parlor 145)
12:15 pm	ISD Physical Chemistry of Steelmaking Committee Luncheon (Parlor 116-117)
2:00 pm	IMD High Temperature Alloys Committee Meeting (Parlor 145)
3:00 pm	Metallurgical Society Publications Committee Meeting (Parlor 108)

Thursday, March 2

9:00 am	MAB Committee Meeting (Parlor 130)

International Experts on Agglomeration to Meet in Philadelphia

The First International Symposium on Agglomeration, sponsored by AIME, will be held April 12-14 at the Sheraton Hotel, Philadelphia. The conference will deal with sintering, pelletizing, nodulizing, briquetting, powder metallurgy, ceramic bonding, and related processes. Areas of application will include ferrous and nonferrous ores, carbonaceous materials, and ceramics and other nonmetallics. All of these phases of the subject will be covered by technical papers being written by specialists from all over the world.

During the six technical sessions, more than 30 papers from 11 countries will be presented in the form of abstracts. Preprints of these papers, with abstracts in English, French, and German, will be mailed to all pre-registrants on March 1, 1961.

Prepared discussions will be presented and, if time permits, spontaneous discussions. All technical papers accepted for the Symposium, together with discussions, will be published in a bound volume and will be mailed to all registrants promptly after the Symposium. Non-registrants who are AIME members will be able to secure copies of the Proceedings for about $20, nonmembers for about $25.

The official language of the Symposium and all functions will be in English. German and French interpreters will be available at all functions and sessions and will wear color bars indicating:

English—White
French—Blue
German—Red

arranged in various combinations. Non-English speaking registrants who wish to present oral discussion during the session should present a written outline to the Language Coordinator at the Registration Desk at least one day in advance.

A special feature, designed to save time during the technical sessions, is the daily luncheon at which authors of papers will preside at specifically marked tables, giving each person an opportunity to sit with an author and discuss his paper.

Program

(Subject to Change)

Technical Session 1—Wednesday April 12, 1961—8:30 am to 12:00 noon

Pelletizing Characteristics of Raw Mixes for Cement Manufacturing by J. R. Tonry, Portland Cement Assoc.
Microstructure in Binderless Briquetting by O. G. Ingles, Commonwealth Scientific & Industrial Research Organization, Melbourne, Australia.
Compacting and Sintering of Metal Powders Without the Application of Pressure by H. H. Hausner, Consulting Engineer.
The Properties of Active Ceramic Oxide Powders in Relation to Sintering Behavior by P. Murray, United Kingdom Atomic Energy Authority, Harwell.
An Evaluation of the Properties of Dolomites Affecting Self-Fluxing Sinter Rates by R. A. Limons and H. M. Kraner, Bethlehem Steel Co.

Welcoming Luncheon—Wednesday April 12, 1961—12:15 pm—AIME President R. R. McNaughton, speaker.

Technical Session 2—Wednesday April 12, 1961—2:00 pm to 5:30 pm.

Tumbling Resistance and Reducibility Tests for Evaluating Nickel Silicate Ore Sinters by T. D. de Souza Santos, Institute de Pesquisas Technologicas, Sao Paulo, Brazil.
Properties of Sinter Smelted in the Electrothermic Zinc Furnace by D. E. Warnes, St. Joseph Lead Co.
Advances in Balling and Pelletizing by H. T. Stirling, Koppers Co.
Preparation of the Raw Material Charge in the Sintering of Lead Concentrates by D. Ingvoldstad and K. Kirkpatrick, The Bunker Hill Co.
Dynamics of Pelletization by U. N. Bhrany, R. T. Johnson, and T. L. Myron, U. S. Steel Corp.

Technical Session 3—Thursday April 13, 1961—8:30 am to 12:00 noon.

The Sintering of Mixed Powders by J. White, University of Sheffield, England.
Characterization and Sintering of Powders by H. J. Oel, Max-Planck-Institut fur Silikatforschung, Wurzburg, Neunerplatz, Germany.
The Oxidation Rates of Zinc Sulphide Spheres by G. S. G. Beveridge, University of Edinburgh and Heriot-Watt College, Glasgow.
Rate of Densification in the Sintering of Uncompacted Metal Powders by F. N. Rhines, R. T. DeHoff, and R. A. Rommel, University of Florida.
The Strength of Granules and Agglomerates by H. Rumpf, Lehrstuhl und Institut fur Mechanische Verfahrenenstechnik, Karlsruhe, Germany.

Technical Session 4—Thursday April 13, 1961—8:30 am to 12:00 noon.

Engineering Contributions to New Techniques of Iron Ore Agglomeration by M. J. Greaves and A. English, Arthur G. McKee & Co.
Conventional, Hot Air and Mixed Fired Sintering by H. Rausch and F. Cappel, Lurgi, Frankfurt, Germany.
The Basis of Sinter Plant Design by R. F. Jennings and A. Grieve, Huntington, Heberlein & Co. Ltd., London.
The Continuous Sintering Process-Research and Applications by T. E. Ban, C. D. Thompson, D. C. Violetta, and C. A. Czako, McDowell Co. Inc.
Automation of the Sintering Machine by K. Wada and K. Tsujihata, Yawata Iron and Steel Co. Ltd., Japan.

Luncheon—Author's Table—Thursday April 13, 1961—12:15 pm.

Technical Session 5—Thursday April 13, 1961—2:00 pm to 5:30 pm.

Pressure and Water Gradients Through a Sinter Bed by R. Wild, British Iron & Steel Research Assn.
The Combustion Zone in the Iron Ore Sintering Process by R. Schluter and G. Bitsianes, University of Minnesota.
Heat Hardening of Artificial Magnetite Pellets by W. Callender, The Broken Hill Proprietary Co. Ltd., Australia.
A Progress Report on the Effect of Grind, Temperature, and Pellet Size Upon the Quality of Specular Hematite Pellets by D. M. Urich and Tsu-Ming Han, The Cleveland-Cliffs Iron Co.
Shrinkage of Iron-Ore Pellets During Agglomeration by H. U. Ross and A. Ohno, University of Toronto.

Technical Session 6—Friday April 14, 1961—8:30 am to 12:00 noon.

Hot Briquetting of Partially Reduced Iron Ores by J. E. Moore and D. H. Marlin, Dravo Corp.

Study of the Properties of Self-Fluxing Sinters by W. A. Knepper, R. B. Snow, and R. T. Johnson, U. S. Steel Corp.
Effects of Lime on the Sintering of Pure Hematite and Magnetite Concentrates by O. Nyquist, Jernkontoret, Stockholm, Sweden.
Fundamental Studies of Self-Fluxing Sinter by S. Watanabe, Sumitomo Metal Industries Ltd., Japan.
Structures and Bonding Mechanism in Sinters Made from Fine-Grained Australian Hematites by L. C. Bogan and H. K. Worner, The Broken Hill Proprietry Co. Ltd., Australia.

Luncheon—Author's Table—Friday April 14, 1961—12:15 pm.

Technical Session 7—Friday April 14, 1961—2:00 pm to 5:30 pm.

Pelletizing on a Horizontal Grate Machine by K. M. Haley and W. E. Apuli, Reserve Mining Co.
The Coarse Specularite-Fine Magnetite Pelletizing Process by K. E. Merklin and F. D. DeVaney, Pickands Mather & Co.
The Cooling of Sinter by P. A. Young and D. A. Barnard, Head Wrightson and Co. Ltd., Yorkshire, England.
Factors Controlling the Cooling Rate of Sinter by D. D. Phelps and J. A. Anthes, Dravo Corp.
Limits of the Sinter Process by H.

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Total AIME members on December 31, 1960, was 34,852; in addition 1,893 Student Members were enrolled.

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NECROLOGY

Date Elected	Name	Date of Death
1953	Biegen, Harold	July 1960
1938	Brown, Fayette E.	Dec. 23, 1960
1955	Bruce-Gardner, C.	Nov. 1, 1960
1923	Buchner, Carl F.	Nov. 21, 1960
1916	Butler, B. S.	Nov. 13, 1960
1914	Comstock, E. H.	Apr. 1960
1943	Cree, J. O.	June 13, 1960
1938	Cushwa, Claude C.	Nov. 1, 1960
1954	Darrow, F. R.	Dec. 12, 1960
1928	Fleming, Arthur P. M.	Sept. 14, 1960
1927	Henricksen, Ray M.	Unknown
1919	Hill, Harry P.	Oct. 6, 1960
1951	Hugill, O. H.	Unknown
1948	Mardock, Edwin S.	July 10, 1960
1946	McCan, George W.	Nov. 28, 1960
1956	McClain, Alan H.	May 17, 1960
1956	McCrorey, Geo. T.	Nov. 7, 1960
1949	Muir, Neal M.	Nov. 5, 1960
1949	Nesbitt, M. B.	Nov. 17, 1960
1949	Rhodes, J. R.	Unknown
1958	Rose, C. H.	Sept. 5, 1960
1942	Satterthwaite, H. G.	May 11, 1960
1936	Scallon, E. P.	Nov. 19, 1960
1957	Sears, Hayden F.	Nov. 19, 1960
1920	Smith, Edwin K.	Unknown
1950	Terry, Paul E.	Dec. 2, 1960
1955	Thomas, E. R.	Unknown
1949	Voce, E.	Oct. 26, 1960
1930	Walz, Andrew	1959
1936	Waterman, Geo. H.	Sept. 22, 1960
1917	Wilson, R. R.	Nov. 20, 1960

Education

(Continued from page 119)

ing a 16-page bulletin, *Sintering*, (Bulletin No. 603), which describes the advantages, physical properties, and applications of powdered metal parts, discusses design principles, and illustrates the different types of furnaces that are being used to heat treat the compacts. Copies of the bulletin are available from the Electric Furnace Co., 600 West Wilson St., Salem, Ohio.

Metals Congress . . .

(Continued from page 168)

The final session, **Plasma Arc Applications to Metallurgy** is scheduled for Thursday morning, March 23. J. Winzeler of Plasmadyne Corp., will present a paper on *Plasma Arc Applications to Metallurgy—Technical Parameters, State of the Art, Future Developments in Hardware.* A paper on *Process Variables in Plasma Jet Spraying* will be presented by Mash, Weare, and Wagner of Advanced Technology Laboratories. *Techniques for Spraying Toxic and Oxidizable Materials* will be discussed by A. R. Stetson and C. A. Hauck of Solar Aircraft Co.; and G. D. Smith of E. I. duPont de Nemours & Co., will present a paper on *Plasma Arc Spray Applications for Erosion and Corrosion Service.*

Speakers . . .

(Continued from page 169)

of Mines in 1921. Since 1924, he has been continuously engaged in teaching and research in the mineral field, first as a lecturer in mining at Columbia, and then as associate professor of metallurgical research at the University of Utah. From 1929-39, he was research professor of mineral dressing at the Montana School of Mines. Since 1939 he has been at M.I.T.

Agglomeration . . .

(Continued from page 170)

Wendeborn and F. Cappel, Lurgi, Frankfurt, Germany.

Paper to be printed but not presented: *A Survey of the Literature Pertinent to Iron Ore Pelletizing* by T. K. Goldstick, Jones & Laughlin Steel Corp.

The Registration fee for the Conference is $25 for AIME members, $27.50 for nonmembers. These fees include one set of preprints and one volume of Proceedings. Student fees—$3.50 for AIME student members, $5 for nonmembers—do not include preprints or Proceedings.

Thursday evening has been reserved for the social events of the Conference beginning with an All-Symposium cocktail party, followed by a fellowship dinner at which President Harnwell of the University of Pennsylvania will speak. The ladies are of course welcome and informal dress will be the order of the evening.

For information write: W. B. Stephenson, General Chairman, International Symposium on Agglomeration, P.O. Box 635, Paoli, Pa.

Coming Events

Feb. 10, 1961, Southwestern Section NOHC, Annual All-Day Meeting, Hotel Lennox, St. Louis.

Feb. 20, 1961, Joint Meeting, Detroit NOHC and Detroit AIME Sections, Rackham Building, Detroit.

Feb. 26-March 2, 1961, AIME Annual Meeting, Ambassador and Chase-Park Plaza Hotels, St. Louis, Mo.

Mar. 13-14, 1961, 59th Annual Meeting, Steel Founders' Society of America, Drake Hotel, Chicago.

Mar. 20-22, 1961, Canadian Institute of Mining and Metallurgy, Annual General Meeting, Quebec City, Que., Canada.

Mar. 20-24, 1961, Western Metal Exposition & Congress, Pan Pacific Auditorium, Los Angeles.

Mar. 23, 1961, Northern Ohio Section, NOHC, Annual Off-the-Record Meeting, Pick-Ohio Hotel, Youngstown, Ohio.

Mar. 23-24, 1961, Third Annual Symposium on Electron Beam Technology, Boston.

Apr. 10-12, 1961, 44th National Open Hearth Steel Conference and Blast Furnace, Coke Oven, and Raw Materials Conference, Sheraton Hotel, Philadelphia.

Apr. 10-13, 1961, First International Congress on Metallic Corrosion, Imperial College of Science & Technology, London, England.

Apr. 12-14, 1961, AIME International Symposium on Agglomeration, Sheraton Hotel, Philadelphia.

Apr. 13-15, 1961, Pacific Northwest Metals & Minerals Conference, Spokane, Wash.

Apr. 24-25, 1961, AIME Southwest Minerals Industry Conference, Stardust Hotel, Las Vegas, Nev.

Apr. 26-27, 1961, Cleveland Section and The Metallurgical Society, Technical Conference on High Temperature Materials, Hotel Carter, Cleveland.

May 18-19, 1961, AIME 15th New England Regional Conference, Hotel Van Curler, Schenectady, N. Y.

Aug. 30-Sept. 1, 1961, AIME Third Technical Conference on Semiconductors, Ambassador Hotel, Los Angeles.

Oct. 17-Nov. 7, 1961, Visit of the Iron & Steel Institute (United Kingdom) to the United States.

Oct. 23-26, 1961, Fall Meeting of The Metallurgical Society of AIME, Pick-Fort Shelby Hotel, Detroit.

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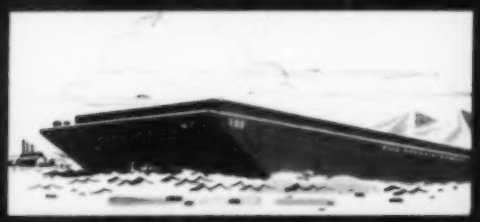
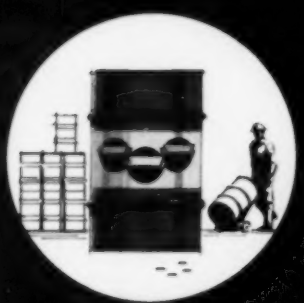
BY  THE BARGELOAD OR...

BY THE DRUM,  YOU

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